

AACE International Certified Cost Technician Primer

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SUPPORTING SKILLS AND KNOWLEDGE OF A COST ENGINEER

Based Upon AACE International Recommended Practice 11R-88,
Required Skills and Knowledge of Cost Engineering

Part 1

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Cost Engineering and Total Cost Management

AACE International is dedicated to the tenets of furthering the concepts of Total Cost Management and Cost Engineering. Total Cost Management is the effective application of professional and technical expertise to plan and control resources, costs, profitability and risk. Simply stated, it is a systematic approach to managing cost throughout the life cycle of any enterprise, program, facility, project, product or service. This is accomplished through the application of cost engineering and cost management principles, proven methodologies and the latest technology in support of the management process.

Total Cost Management is that area of engineering practice where engineering judgment and experience are used in the application of scientific principles and techniques to problems of business and program planning; cost estimating; economic and financial analysis; cost engineering; program and change control.

Cost engineers often specialize in one function with a focus on one side of the asset and project business. They may have titles such as cost estimator, parametric analyst, strategic planner, scheduler, cost/schedule engineer, project manager, or project control lead. They may work for the business that owns and operates the asset (emphasis on economics and analysis), or they may work for the contractor that executes the projects (emphasis on planning and control). But no matter what their job title or business environment, a general knowledge of, and skills in, all areas of cost engineering are required to perform their job effectively.

Purpose of This Document

This Primer provides someone who is preparing to sit for AACE International's Certified Cost Technician (CCT™) certification exam, a detailed outline of the skills and knowledge necessary to successfully achieve this certification.

The Primer is based upon AACE International Recommended Practice 11R-88, Required Skills and Knowledge of Cost Engineering. It is intended to outline what core skills and knowledge of cost engineering a person is required to have in order to be considered a professional practitioner, and in doing so, establish the emphasis of core subjects for AACE International education and certification programs.

This Primer addresses part one of 11R-88, "Supporting Skills and Knowledge." It is recommended that in addition to this document, reading **Skills and Knowledge 6th Edition**, AACE International's **TCM Framework**, and other specialty texts such as Schaum's Beginning Statistics 2nd Edition, Schaum's Statistics Crash Course and economics reference workbooks. The latest reference list can be found at the AACE International website – www.aacei.org.

To successfully pass the CCT exam, there will be problems that must be correctly solved. It is beyond the scope of this primer to provide example problems. CCT candidates can find example problems in publications such as AACE International's S&K 6th Edition, and other reference material, as identified on the certification section of www.aacei.org.

A general caution, while this primer is intended to support one seeking to successfully achieve AACE International's CCT certification, it cannot be substituted for one's actual knowledge and experience. Carefully review the current minimum requirements necessary for achieving any of the AACE certifications at www.aacei.org.

This publication was developed by the AACE International Education Board to assist young professionals in preparing for the AACE International Certified Cost Technician (CCT) exam.

The Education Board will continue to update and improve this document as needed to support the CCT exam. Recommendations and or comments are highly welcomed and should be forwarded to the AACE International Education Board at edchair@aacei.org.

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[AACE International Recommended Practice 11R-88, January 17, 2006]

I. SUPPORTING SKILLS AND KNOWLEDGE

1. Elements of Cost

A. Costs:

- Cost - In project control and accounting, it is the amount measured in money, cash expended or liability incurred, in consideration of goods and/or services received. From a total cost management perspective, cost may include any investment of resources in strategic assets including time, monetary, human, and physical resources [RP 10S-90].
- Cost – Is the value of an activity or asset. Generally, this value is determined by the cost of the resources that are expended to complete the activity or produce the asset. Resources used are categorized as material, labor, and “other”. Although money and time are sometimes thought of as resources, they only implement and/or constrain the use of the physical resources just listed. The “other” cost category consists of resources needed to support the activity and/or asset. An example would be the facilities needed to produce an activity or asset, which would include the tooling, electricity, taxes, and maintenance, etc., necessary to keep the facility available for use. Other costs might be office supplies, communication costs, travel costs, and security costs [S&K 6th Ed., 1.1. 1.2].

1. Resources

- Any consumable, except time, required to accomplish an activity. From a total cost and asset management perspective, resources may include any real or potential investment in strategic assets including time, monetary, human, and physical. A resource becomes a cost when it is invested or consumed in an activity or project [RP10S-90].

[Refer to S&K 6th Edition, Chapter 1, for more detailed discussion on this topic]

B. Cost Dimensions:

1. Lifecycle:

- The stages or phases that occur during the lifetime of an object or endeavor. A life cycle presumes a beginning and an end with each end implying a new beginning. In life cycle cost or investment analysis, the life cycle is the length of time over which an investment is analyzed (i.e., study period) The following are typical life cycles:
 - ✓ **Asset Life Cycle** – the stages or phases of asset existence during the life of an asset. Asset life cycle stages typically include:
 - **Ideation** –recognize an opportunity or need for a new or improved asset; evaluate research, develop and define optional asset solutions that address the opportunity; and select an optimum asset solution.
 - **Creation** – create or otherwise implement the asset solution through execution of a project or program.
 - **Operation** – deploy or put the new or modified asset into service, function, production, operation, or other use.
 - **Modification** –improve, modify, or otherwise change or recycle the asset through execution of a project or program.

- **Termination** – decommission, close, retire, demolish, remove, dispose, or otherwise terminate the asset from the enterprise’s portfolio (often through execution of a project or program) [TCM Framework, 2.1.3].
- ✓ **Product Life Cycle** – Complete history of a product through its concept, definition, production, operation, and obsolescence or disposal phases. The distinction between product life cycle and project life cycle is that the latter does not include the last two phases.
- ✓ **Project Life Cycle** – The stages or phases of project progress during the life of a project. Project life cycle stages typically include:
 - **Ideation** – given overall requirements of the project, the project team assesses alternative concepts for performing the project and selects an optimal performance strategy. Strategic performance requirements for projects are established.
 - **Planning** – project plans are developed that address the strategic requirements and selected performance strategy.
 - **Execution** – the plans are implemented through the execution of planned project activities.
 - **Closure** – the asset or deliverable is reviewed, tested, verified, validated, and turned over to the customer. Learning for future use in ideation is documented.
[RP 10S-90; TCM Framework, 2.1.4]

2. Process (Product vs. Project)

- **Process** – Sequence or independent and linked procedures which, at every stage, consume one or more resources (employee time, energy, machines, money) to convert inputs (data, material, parts. Etc.) into outputs. These outputs then serve as inputs for the next stage until a known goal or end result is reached [Business Dictionary.com].
- **Product**
 - 1) **General:** Good, idea, method, information, object, service, etc, that is the end result of a process and serves as a need or want satisfier. It is usually a bundle of tangible and intangible attributes (benefits, features, functions, uses) that a seller to a buyer for purchase [Business Dictionary.com].
 - 2) **Law:** Commercially distributed good that is (1) tangible personal property, (2) output or result of a fabrication, manufacturing, or production process, and (3) passes through a distribution channel before being consumed or used [Business Dictionary.com].
 - 3) **Marketing Mix:** Good or service that most closely meets the requirements of a particular market or segment and yield enough profit to justify its continued existence [Business Dictionary.com].
- **Co-Product**

- ✓ Product manufactured along with a different product, in a process in which both are required in the production of another product. In comparison, a by-product is usually an undesirable product. Business Dictionary.com.

- **By-Product**

- ✓ Output other than the principal product(s) of an industrial process, such as sawdust or woodchips generated in processing lumber. Unlike joint-products, byproducts have low value in comparison with the principal product(s) and may be discarded or sold either in their original state, or after further processing [Business Dictionary.com].

3. Responsibility:

- **Owners View Costs**

- ✓ The owner approaches cost from a holistic point of view. Owners not only consider the cost of the construction, or process, but internal supervision and overhead, implementation costs, cost of money, furniture, fixtures, equipment(FFE) and other considerations. It is the responsibility of the owner or the owner's representative, to clearly communicate the project or process intent and the desired outcome. The owner or stakeholders have expectations on the value received from the project and the return on their investment.
- ✓ Contractors, subcontractors, suppliers only consider their part of the project costs and are responsible for that alone.

4. Valuation:

- **Valuation**

- ✓ **General:** Appraising or estimating the worth of something having economic or monetary value. Business Dictionary.com
- ✓ **Insurance:** Determination of the worth of the asset to be insured or that which has been damaged or lost. Business Dictionary.com
- ✓ **International Trade:** Determination of the dutiable value of imports by the customs authorities.

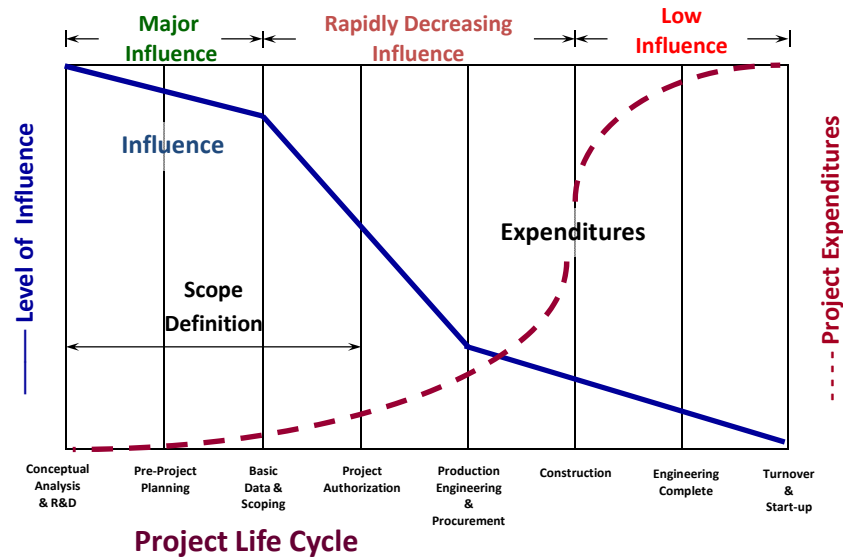
- **Opportunity Costs**

- ✓ The cost of an alternative that must be forgone in order to pursue a certain action. Put another way, the benefits you could have received by taking an alternative action. Investopedia.com
- ✓ Economic decision makers needed to consider the impact of opportunity costs. An opportunity cost represents the foregone benefit by choosing one alternative over another [S&K 6th Ed. 72].

5. Influence:

- There is a relationship between time and the opportunity to influence a project's cost. The more time that has elapsed, the less the chance to alter the cost. It is important to make the cost effective decisions early in a project or process to have the most influence on cost. This is known as the "Cost – Influence Curve."

Opportunity for Influence



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6. Legal:

1. Be able to explain how cost and schedule analysis practices might differ when applied for forensic versus traditional planning and control purposes.
2. Be able to describe some potential legal consequences that may result from using poor or unethical cost management practices (e.g., anti-trust, claims, Sarbanes-Oxley, etc)

C. Cost Classifications:

1. Operating (Production, Manufacturing, Maintenance, etc.) vs. Capital

- **Operating Costs** – The expenses incurred during the normal operation of a facility, or component, including labor, materials, utilities, and other related costs. Includes all fuel, lubricants, and normally scheduled part changes in order to keep a subsystem, system, particular item, or entire project functioning. Operating costs may also include general building maintenance, cleaning services, taxes, and similar items [RP10S-90].
- **Manufacturing Cost** – The total of variable and fixed or direct and indirect costs chargeable to the production of a given product, usually expressed in cents or dollars per unit of production, or dollars per year. Transportation and distribution costs, and research, development, selling and corporate administrative expenses are usually excluded [RP10S-90].
- **Maintenance Costs** – The total of labor, material, and other related costs incurred in conducting corrective and preventative maintenance and repair on a facility, on its systems and components, or on both. Maintenance does not usually include those items that cannot be expended within the year purchased. Such items must be considered as fixed capital [RP10S-90].

- **Capital, Fixed** – The total original value of physical facilities which are not carried as a current expense on the books of accounting and for which depreciation is allowed by the US federal government, It includes plant equipment, building, furniture and fixtures, and transportation equipment used directly in the production of a product or service. It includes all costs incident to getting the property in place and in operating condition, including legal costs, purchased patents, and paid-up licenses. Land, which is not depreciated, is often included. Characteristically it cannot be converted readily into cash [RP10S-90].

2. **Capital vs. Expense**

a. **Depreciation**

- Decline in value of a capitalized asset [RP10-S90].
- A form of capital recovery applicable to a property with a life span of more than one year, in which an appropriate portion of the asset's value is periodically charged to current operations [RP10-S90].

b. **Amortization**

- As applied to a capitalized asset, the distribution of the initial cost by periodic charges to operations as in depreciation. Most properly applies to assets with indefinite life [RP10S-90].
- The reduction of a debt by either periodic or irregular payments [RP10S-90].
- A plan to pay off a financial obligation according to some prearranged schedule [RP10S-90].

c. **Accrual**

- In finance, the adding together of interest or different investments over a period of time. It holds specific meanings in accounting, where it can refer to accounts on a balance sheet that represents liabilities and non-cash based assets used in accrual-based accounting. These types of accounts include, among others, accounts payable, accounts receivable, goodwill, deferred tax liability and future interest expense [wikipedia.org].
- Accounting method that records revenues and expenses when they are incurred, regardless of when cash is exchanged. The term accrual refers to any individual entry recording revenue or expense in the absence of a cash transaction [Entrepreneur.com].
- Accrued revenue (or accrued assets) is an asset, such as unpaid proceeds from a delivery of goods or services, when such income is earned and a related revenue item is recognized, while cash is to be received in a latter period, when the amount is deducted from accrued revenues [Wikipedia.org].
- Accounts on a balance sheet that represent liabilities and non-cash based assets used in accrual-based accounting. By using accruals, a company can measure what it owes looking forward and what cash revenue it expects to receive. It also allows a company to show assets that do not have a cash value, such as goodwill [Investopedia.com].

d. **Expense**

- Expenditures of short-term value, including depreciation, as opposed to land and other fixed capital [RP10S-90].

3. Fixed vs. Variable

- **Fixed Cost** – Those costs independent of short term variations in output of the system under consideration. Includes such costs as maintenance; plant overhead; and administrative, selling and research expense. For the purpose of cash flow calculation, depreciation is excluded (except in income tax calculations). In construction this includes general and administrative costs [RP10S-90].
- **Fixed Costs** – Fixed costs are those cost elements that must be provided independent of the volume of work activity or asset production that they support. These can be either direct or indirect costs [S&K 6th Ed., 12].
 - ✓ Depreciation
 - ✓ Property taxes
 - ✓ Insurance
- **Variable Costs** – Those costs that are a function of production, e.g., raw materials costs, by-product credits, and those processing costs that vary with plant output (such as utilities, catalysts and chemical, packaging, and labor for batch operations) [RP10S-90].
- **Variable Costs** – Variable costs are those cost elements that must be provided and are dependent on the volume of work activity or asset production that they support [S&K 6th Ed., 12].
 - ✓ Raw materials
 - ✓ Utilities
 - ✓ Royalties
 - ✓ Packaging
 - ✓ Marketing
 - ✓ Catalysts and chemicals

4. Direct vs. Indirect

- **Direct Cost** – Costs of completing work that are directly attributable to its performance and are necessary for its completion. 1) In construction: the cost of installed equipment, material, labor and supervision directly or immediately involved in the physical construction of the permanent facility. 2) In manufacturing, service, and other non-construction industries: the portion of operating costs that is readily assignable to a specific product or process area [RP10S-10].
 - ✓ **Direct Cost** – Direct costs are those resources that are expended solely to complete the activity or asset [S&K 6th Ed.,11].
- **Indirect Cost**
Indirect costs are those resources that need to be expended to support the activity or asset but that are also associated with other activities and assets. Indirect costs are allocated to an activity or asset based upon some direct cost element, such as labor hours,

material cost or both. Indirect costs also may be referred to as “overhead costs” or “burden costs.”

- ✓ Costs not directly attributable to the completion of an activity. Indirect costs are typically allocated or spread across all activities on a predetermined basis.
- ✓ In construction, all costs which do not become a final part of the installation, but which are required for the orderly completion of the installation and may include, but are not limited to, field administration, direct supervision, capital tools, startup costs, contractor’s fees, insurance, taxes, etc.
- ✓ In manufacturing, costs not directly assignable to the end product or process, such as overhead and general purpose labor, or costs of outside operations, such as transportation and distribution. Indirect manufacturing cost sometimes includes insurance, property taxes, maintenance, depreciation, and packaging, warehousing and loading [RP10S-90].

a. **Activity-Based Costing (ABC)**

- The most significant cost accounting technique of interest to cost engineering and strategic asset management is activity-based cost management (ABC/M) which improves upon traditional cost accounting by assigning costs to the work activities and then to the assets that drive the workload. This superior costing method based on cause-and-effect relationships is in contrast to simply capturing the spending expenses in cost centers and making somewhat arbitrary guesses or using broad averages (e.g., number of units produced) as to the relationship of the costs to the assets that are uniquely consuming the various types of costs. Traditional cost allocations leads to simultaneous over-costing and under-costing of outputs relative to their actual costs [TCM Framework, 5.1.1].
- A key difference between ABC/M and the general ledger and traditional techniques of cost allocations (i.e., absorption costing) is that ABC/M describes activities using an “action-verb-adjective-noun” grammar convention, such as inspect defective products, open new customer accounts, or process customer claims. This gives ABC/M its flexibility. Such wording is powerful because managers and employee teams can better relate to these phrases, and the wording implies that the work activities can be favorably affected, changed, improved, or eliminated. The general ledger uses a chart of accounts, whereas ABC/M uses a chart of activities. In translating general ledger data to activities and processes, ABC/M preserves the total reported revenues and costs but allows the revenues, budgeted funding, and costs to be viewed differently [S&K 6th Ed., 843].

b. **Job Costing**

- **Order-specific costing technique**, used in situations where each job is different and is performed to the customer’s specifications. Job costing involves keeping an account of direct costs (labor, machine time, raw materials) and indirect costs (overheads) [Business Dictionary.com].
- **Job costing** involves the calculation of costs involved in a construction “job” or the manufacturing of goods done in discrete batches. These costs are recorded in ledger accounts throughout the life of the job or batch and are then summarized in the final trial balance before the preparation of the job cost or batch manufacturing statement [Wikipedia.org].

- **Job costing** (known by some as job order costing) is fundamental to managerial accounting. It differs from Process costing in that the flow of costs is tracked by job or batch instead of by process. Process costing is used when the products are more homogeneous in nature [Wikipedia.org].

D. **Cost Types:**

1. **Materials:**

1. **Materials Types:**

a. **Raw**

- Raw materials are those materials used in a production or fabrication process that require a minimum amount of processing to be useful [S&K 6th Ed., 27].
- Depending upon the particular process, raw materials costs can constitute a major portion of operating costs. For this reason, a complete list of all raw materials must be developed using the process flow sheet as a guide [S&K6th Ed., Chap 3].
- Includes products entering the market for the first time which have not been fabricated or manufactured but will be processed before becoming finished goods. (e.g., steel scrap, wheat, raw cotton) [RP 10S-90].

b. **Bulk**

- The steel product can be considered to be a bulk material in all of its various forms, including sheet steel, steel bars, steel pipe, and structural steel shapes, such as wide flange beams and angles. The bulk materials category is distinguished by its availability. Bulk materials in common sizes are typically readily available with minimal lead times for order and delivery [S&K 6th Ed., 27].
- Material bought in lots. These items can be purchased from a standard catalog description and are bought in quantity for distribution as required. Examples are pipe, conduit, fittings and wire [RP 10S-90].
- Other types of bulk material would be gravel, select soil and sand

c. **Fabricated**

- Fabricated materials are bulk materials transformed into custom-fit items for a particular product or project [S&K 6th Ed., 27].

d. **Engineered or Designed**

- Engineered or designed materials constitute a category requiring substantial working in order to attain their final form. Design or engineered materials are also based on shop drawings [S&K 6th Ed., 27].

e. **Consumables**

- Supplies and materials used up during construction. Includes utilities, fuels and lubricants, welding supplies, worker's supplies, medical supplies, etc. [RP10S-90].

2. **Purchase Costs:** Listed below are some items that can affect the purchase costs of materials:

- a. market pricing (pre-negotiated vs. competitively bid, etc.)

- b. order quantity
- c. taxes and duties
- d. carrying charges
- e. cancellation charges
- f. demurrage
- g. hazardous material regulations
- h. warranties, maintenance and service

3. **Materials Management Costs:** Listed below are items that can affect the management cost of materials:

- a. delivery schedule
- b. packing
- c. shipping and freight
- d. freight forwarding
- e. handling
- f. storage and inventory
- g. agent cost
- h. surveillance or inspection
- i. expediting
- j. losses (shrinkage, waste, theft, damage)
- k. spare parts (inventory or start-up)
- l. surplus materials

4. **Capital Equipment:** (i.e., fabricated or engineered items)

Equipment that you use to manufacture a product, provide a service or use to sell, store and deliver merchandise. This equipment has an extended life so that it is properly regarded as a fixed asset [Entrepreneur.com].

a. **Rent vs. lease vs. purchase:**

- **Leasing offers some of the following advantages**

- ✓ Minimal upfront cash outlay
- ✓ Not a loan so it does not tie up your line of credit
- ✓ Maintenance agreement, service by others
- ✓ Possible tax advantage as the lease is an expense and may be able to reduce overall tax liability
- ✓ May include a purchase option

- **Renting offers some of the following advantages**

- ✓ Keep work progressing when there is an equipment breakdown
 - ✓ Meet specialty job requirements
 - ✓ Very efficient for low-percentage utilization
 - ✓ Short-term peak or seasonal use
 - ✓ Considered to evaluate equipment for purchase
 - ✓ Fill in for equipment being repaired
 - ✓ Can be returned at any time, not a guaranteed amount of time
 - ✓ Maintenance is usually handled by dealer or rental yard
 - ✓ Can conserve company capital
 - ✓ Can have an option to buy clause
- [Reference Construction Contracting 6th Edition]

- **Purchasing**

When deciding when to purchase and register capital equipment on your books, there are two lines of thinking [Entrepreneur.com].

- ✓ The first is to purchase and install the needed equipment at a point during the year where additional volume warrants the expenditure, thereby assuring sufficient cash flow to handle the additional debt service or the outright purchase of the equipment [Entrepreneur.com].
- ✓ The second is to have the equipment purchased and installed at the beginning of the business year or quarter closest to the time when you will actually need the equipment, allowing time for training and working out bugs before the equipment is placed into full production [Entrepreneur.com].

Each enterprise will need to perform its own financial analysis on the lease vs. purchase option. Many equipment suppliers have easy to use rate calculators that can give the “big” picture costs to assist the decision.

b. **Valuation:**

- **Reproduction Costs**

- ✓ The cost of reproducing substantially the identical item or facility at a price level as of the date specified [RP10S-90].

- **Replacement Costs**

- ✓ The cost of replacing the productive capacity of existing property by another property of any type, to achieve the most economical service, at prices as of the date specified. (2) Facility component replacement and related costs, included in the capital budget, that are expected to be incurred during the study period [RP10S-90].
- ✓ Is the cost new of an item having the same or similar utility [S&K 6th Ed., 57].

- **Fair Value**

- ✓ That estimate of value of a property that is reasonable and fair to all concerned, after every proper consideration has been given due weight [RP10S-90].
- ✓ Is the adjusted cost new of an item, giving consideration for the cost of similar items, and taking into account utility and all standard adjustments and discounts to list price [S&K 6th Ed., 57].

- **Market Value**

- ✓ The monetary price upon which a willing buyer and a willing seller in a free market will agree to exchange ownership, both parties knowing all the material facts but neither being compelled to act. The market value fluctuates with the degree of willingness of the buyer and seller and with the conditions of the sale. The use of the term market suggests the idea of barter. When numerous sales occur on the market, the result is to establish fairly definite market prices as the basis of exchanges [RP10S-90].

- **Fair Market Value-in-Place** is the amount expressed in terms of money that may reasonably be expected to exchange between a willing buyer and a willing seller with equity to both, neither under any compulsion to buy or sell, and both fully aware of all relevant facts as of a certain date, and taking into account installation and the contribution of the item to the operating facility [S&K 6th Ed., 57].
 - **Fair Market Value-in-Exchange** is the value of equipment in terms of the money that can be expected to be exchanged in a third-party transaction between a willing buyer, who is under no compulsion to buy, and a willing seller, who is under no compulsion to sell, both being fully aware of all relevant facts (also referred to as retail value) [S&K 6th Ed., 57].
 - **Orderly Liquidation Value** is the probable price for all capital assets and equipment in terms of money that could be realized from a properly executed orderly liquidation type of sale, given a maximum time of six months to conduct such sale and adequate funds available for the remarketing campaign. (also referred to as wholesale value) [S&K 6th Ed., 57].
 - **Forced Liquidation Value** is the value of equipment in terms of money that can be derived from a properly advertised and conducted auction where time is of the essence (also referred to as “under the hammer” or “blow-out” value) [S&K 6th Ed., 57].
 - **Salvage Value/Part-Out Value** is the value of equipment in terms of money that a buyer will pay to a seller, recognizing the component value of parts of the equipment that can be used or resold to end-users, usually for repair or replacement purposes [S&K 6th Ed., 57].
 - **Scrap Value** is the value of equipment in terms of money that relates to the equipment’s basic commodity value [S&K 6th Ed., 58].
- **Book Value (NET)**
 - (1) Current investment value on the books calculated as original value less depreciated accruals.
 - (2) New asset value for accounting use.
 - (3) The value of an outstanding share of stock of a corporation at any one time, determined by the number of shares of that class outstanding [RP10S-90].
 - **Residual or Economic Value**
 - ✓ The value of property in view of all its expected economic uses, as distinct from its value in view of any particular use. Also, economic value reflects the importance of a property as an economic means to an end, rather than as an end in itself [RP10S-90].

- c) **Operating Cost**
 - ✓ The expenses incurred during the normal operation of a facility, or component, including labor, materials, utilities, and other related costs. Includes all fuel, lubricants, and normally scheduled part changes in order to keep a subsystem, system, particular item, or entire project functioning. Operating costs may also include general building maintenance, cleaning services, taxes, and similar items [RP10S-90].
- 5. **Temporary Equipment:** (expensed items for construction, maintenance, etc)

2. Labor

- 1. **Labor Wage Rate or Salary:** [Review S&K 6th Edition, Chapter 4, for more detailed discussion of this topic].
 - a. Be able to describe the components of wage compensation.
 - **Wage Rate**
 - ✓ Labor cost per work hour where the labor cost includes only wages and not benefits, burdens, or other markups [RP10S-90].
 - **Labor Hour**
 - ✓ A worker hour of effort [RP10S-90].
 - **Labor Burden**
 - ✓ Taxes and insurances the employer is required to pay by law based on labor payroll, on behalf of or for the benefit of labor. (In the US these are federal old age benefits, federal unemployment insurance tax, state unemployment tax, and worker's compensation) [RP10S-90].
 - **Labor Cost**
 - 1) **Bare Labor**
 - ✓ Gross direct wages paid to the worker
 - 2) **Burdened Labor**
 - ✓ Gross direct wages paid to the worker, plus labor burden.
 - 3) **All in Labor**
 - ✓ Gross direct wages paid to the worker, plus labor burden, plus field indirects, plus general & administrative costs, plus profit [RP10S-90].
 - **Exempt Employees**
 - ✓ Employees exempt from overtime compensation by federal wage and hours guidelines [RP10S-90].
 - **Non-Exempt Employees**
 - ✓ Employees not exempt from overtime compensation by US federal wage and hours guidelines [RP10S-90].
 - b. Be able to calculate an effective wage rate allowing for:
 - **Overtime Premium**
 - ✓ Various overtime compensation structures exist based on varying workweek schedules, often based on regional practices.

- **Other Premium Pays**
 - **Shortened Shift Time**
 - ✓ Job conditions may warrant a shortened time shift. Restricted work hours resulting from existing activities that must remain open. Loss of time resulting from security checks could be another.
 - **Travel Time**
 - ✓ Consideration for workers time if the project site is remote from normal residence or hotels if on per diem.
 - **Show-up Pay**
 - ✓ Some contracts, predominately union, would compensate workers who show up to work as scheduled but are sent home for lack of work that day.
2. **Benefits and Burdens (mandated and fringe):** Note: current exam and this document are US centric. Below are some typical examples of US burdens.
- a. Be able to describe the basic mechanics of benefits and burdens such as:
- **Retirement (Social Security),**
 - ✓ Social Security (FICA) wages set aside for retirement [R.S.Means R012909-85].
 - **Unemployment Insurance**
 - ✓ State unemployment tax rates vary not only from state to state, but also with the experience rating of the contractor. The US federal unemployment tax rate is also carried [R.S. Means R012909-85].
 - **Workers Compensation**
 - ✓ Workers Compensation rates vary not only from state to state, trade to trade, but also with the experience rating of the contractor [R.S. Means R013113-60].
 - **Insurance**
 - ✓ Some firms and labor contracts include contributions to a medical and life insurance program. These costs usually can be calculated on an hourly, weekly, or monthly cost basis, and added to the per hour work cost [S&K 6th Ed., 35].
 - **Paid Time Off (Sick, Vacation, Holiday)**
 - ✓ Most employees have additional benefits of time off for local and US national holidays, vacation, and sick time. Therefore, in developing a unit cost for labor, a factor is added to increase the estimated and booked cost per hour worked each week to cover PTO. In the case of a construction craft that may work for many employers during a given period, wages are usually paid into a fund managed by their union or trade organization, who then distributes the salary for PTO [S&K 6th Ed., 35].
3. **Overhead and Profit:**

- **Overhead** [Review S&K 6th Edition, Chapter 4, for more detailed discussion on this topic].
 - ✓ A cost or expense inherent in the performing of an operation, (e.g., engineering, construction, operating, or manufacturing) which cannot be changed to or identified with a part of the work, product or asset and, therefore, must be allocated on some arbitrary base believed to be equitable, or handled as a business expense independent of the volume of production. Plant overhead is also called factory expense [RP10S-90].
 - ✓ **General:** Resource consumed or lost in completing a process, but which does not contribute directly to the end-product. Also called burden cost [Business Dictionary.com].
 - ✓ **Accounting:** Cost or expense (such as for administration, insurance, rent, and utility changes) that (1) relates to an operation or the firm as a whole, (2) does not become an integral part of a good or service (unlike raw material or direct labor), and (3) cannot be applied or traced to any specific unit of output. Overheads are indirect costs [Business Dictionary.com].
 - ✓ **Utilities:** Energy or water lost during delivery from the generating or production plant to the end user [Business Dictionary.com].

- **General and Administrative Costs (G&A)**
 - ✓ The fixed cost incurred in the operation of a business. G&A costs are also associated with office, plant, equipment, staffing, and expenses thereof, maintained by a contractor for general business operations. G&A costs are not specifically applicable to any given job or project [RP10S-90].

- **Profit**
 - ✓ **Gross Profit** – Earnings from an on-going business after direct and project indirect costs of goods sold have been deducted from sales revenue for a given period [RP10S-90].
 - ✓ **Net Profit** – Earnings or income after subtracting miscellaneous income and expenses (patent royalties, interest, capital gains) and federal income tax from operating profit [RP10S-90].
 - ✓ **Operating Profit** – Earnings or income after all expenses (selling, administrative, depreciation) have been deducted from gross profit [RP10S-90].
 - ✓ Best known measure of the success of an enterprise, it is the surplus remaining after total costs are deducted from total revenue, and the basis on which tax is computed and dividend is paid. Profit is reflected in reduction in liabilities, increase in assets, and / or increases in owner's equity. It furnishes resources for investing in future operations, and its absence may result in the extinction of the firm. As an indicator of comparative performance, however, it is less valuable than return on investment (ROI). In economics, total cost must include a cost to cover the normal profit for the firm. Also called earnings, gain, or income [Business Dictionary.com].

- a. **Indirect Labor** (Home Office, Administrative and Similar Costs)

- ✓ The labor needed for activities that do not become part of the final installation, product or goods produced, but that are required to complete the project.
- b. **Small Tools**
- ✓ Small tools and consumables are required to perform the work but not part of the final installation. Generally derived by a percentage of the material cost.
4. **Union: - Non-Union**
- **Union**
 - ✓ An organization of wage earners formed for the purpose of serving the members' interests with respect to compensation and working conditions [RP10S-90].
 - **Open Shop**
 - ✓ An employment or project condition where either union or non-union contractors or individuals may be working. Open shop implies that the owner or prime contractor has no union agreement with workers [RP10S-90].

Hint: Be able to explain the cost differences between union and open shop labor. Based on union wages or open shop wages (Davis Bacon) *

The Davis Bacon Act of 1931 is a US federal law which established the requirement for paying prevailing wages on public works projects. All US federal government construction contracts, and most contracts for US federally assisted construction over \$2,000, must include provisions for paying workers on-site no less than the locally prevailing wages and benefits paid on similar projects.

2. **Subcontract:** be able to explain the cost implications of the following issues:

1. **Reimbursable vs. non-reimbursable costs**
 - ✓ Reimbursable expenses are amounts expended by an employee for and on behalf of the firm, and refundable under the firm's rules [Business Dictionary.com].
2. **Overhead and Profit** (including contract administration and legal costs) See above for detailed description.
3. **License, fees or royalties.**
4. **Bonds (bid, payment, or performance)**
 - ✓ Performance bonds are essentially an insurance policy that the work will be completed. The rates offered to a contractor are based on how financially sound and capable a contractor has demonstrated themselves to be. Actual rates vary from contractor to contractor, and from bonding company to bonding company. Care should be taken to ascertain the bonding capacity of a contractor prior to award.
 - ✓ **Bid Bonds** – A bond that guarantees the bidder will enter into a contract on the basis of the bid [RP10S-90].

- ✓ **Payment Bond** – A bond that is executed in connection with a contract and which secures the payment of all persons supplying labor and materials in the prosecution of the work provided for in the contract [RP10S-90].
- 5. **Retention (Retainage)**
 - ✓ Usually refers to a percent of contract value retained by the purchaser until work is finished and testing of equipment is satisfactorily completed [RP10S-90].
- 6. **Performance Guarantees**
 - See bonds above
- 7. **Bonus – Penalty** – A contractual arrangement between a client and a contractor wherein the contractor is provided a bonus, usually a fixed sum of money, for each day the project is completed ahead of a specified schedule and/or below a specified cost, and agrees to pay a similar penalty for each day of completion after the schedule date or over a specified cost up to a specified maximum either way. The penalty situation is sometimes referred to as liquidated damages [RP10S-90].
- 8. **Liquidated Damages**
 - ✓ An amount of money stated in the contract as being the liability of a contractor for failure to complete the work by the designated time(s). Liquidated damages ordinarily stop at the point of substantial completion of the project or beneficial occupancy by the owner. Also can apply to contract defined output performance [RP10S-90].

3. **Cost of Money:** be able to describe these costs:

1. **Escalation**
 - ✓ The provision in actual or estimated costs for an increase in the cost of equipment, material, labor, etc., over that specified in the purchase order or contract due to continuing price level changes over time. Inflation may be a component of escalation, but non-monetary policy influences, such as supply-and-demanded, are often components [RP10S-90].
 - ✓ Escalation is a technique to accommodate price increases or decreases during the life of the contract. An escalation or de-escalation clause is incorporated into the contract so that the purchaser will compensate the supplier in the event of price changes. These escalation and de-escalation clauses help to shield both the supplier and the purchaser from unpredictable cost changes. Without such clauses, suppliers would include contingency amounts that might later be found to be unrealistically high [S&K 6th Ed., 74].
2. **Inflation**
 - ✓ A persistent increase in the level of consumer prices, or a persistent decline in the purchasing power of money, caused by an income in available currency and credit beyond the proportion of available goods and services. Normally derives from government monetary policy, whereby government debt can be repaid more cheaply [RP10S-90].

- ✓ Inflation is a rise in the price level of a good or service or market basket of goods and/or services. Inflation does not occur by itself but must have a driving force behind it. There are four effects that can result in inflation either by themselves or in combination with other effects. These four are:

- 1) **Money Supply** – is influenced by the central bank of a country.
- 2) **Exchange Rate** – can impact inflation by influencing the price of imported goods and services.
- 3) **Demand-Pull Inflation** – is when excessive quantities of money are chasing a limited amount of goods and services resulting in what is essentially a “seller’s market” as sellers receive premium prices.
- 4) **Cost-Push Inflation** – takes place when product producers encounter higher costs and then push these costs along to others in the production chain through higher prices. These higher costs may be for labor, material, or any other item with a significant cost element [S&K 6th Ed., 73].

3. **Currency Exchange Rates** – Currency changes can have a significant cost impact both on those inside the country as well as those outside the country. Currency prices are set in markets around the world and change on a constant basis as the result of daily trading fluctuations and moves by central banks. Therefore, the currency fluctuations in one country or many countries can have an overall impact on earnings. Financial assets held in one country can witness a significant decline in value if that country's currency is devalued by the central bank. Protecting against currency variations is complicated and can be accomplished through currency futures hedging or valuing contracts against very stable currencies, to cite two examples [S&K 6th Ed., 74].

4. **Risk and Uncertainty:** Be able to describe these costs:

Project-Specific Risks are uncertainties (threats or opportunities) related to events, actions, and other conditions that are specific to the scope of a project (e.g., weather, soil conditions, etc.). The impacts of project-specific risk are more or less unique to a project. The historically inconsistent project-specific nature of the risk-to-impact relationship favors the use of more deterministic methods of quantification such as expected value calculations. A risk taxonomy designation used to classify project risks for the purpose of selecting a quantification method (i.e., contingency determination) [RP10S-90].

1. **Contingency**

- An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in adding costs. Typically estimated using statistical analysis or judgment based on past asset or project experience. Contingency usually excludes:
 - 1) Major scope changes such as changes in end product specification, capacities, building sizes, and location of the asset or project;
 - 2) Extraordinary events such as major strikes and natural disasters;
 - 3) Management reserves; and
 - 4) Escalation and currency effects.Some of the items, conditions, or events for which the state, occurrence, and or effect is uncertain include, but are not limited to, planning and estimating errors and omissions, minor price fluctuations (other than general escalation), design developments and changes within the scope, and variations in market and environmental conditions. Contingency is generally included in most estimates, and is expected to be expended [RP10S-90].

- To an estimator, contingency is an amount used in the estimate to deal with the uncertainties inherent in the estimating process. The estimator regards contingency as the funds added to the originally derived point estimate to achieve a given probability of not overrunning the estimate (given relative stability of the project scope and the assumptions upon which the estimate is based). Contingency is required because estimating is not an exact science. One definition of an estimate is that it is the expected value of a complex equation of probabilistic elements, each subject to random variation within defined ranges. Since the value assigned to each individual component of an estimate is subject to variability, the estimate total itself is also subject to variation [S&K 6th Ed., 118].

2. Allowance

- Resources included in estimates to cover the cost of known but undefined requirements for an individual activity, work item, account or sub-account [RP10S-90].
- Allowances are often included in an estimate to account for the predictable but indefinable costs associated with project scope. Allowances are most often used when preparing deterministic or detailed estimates. Even for this class of estimate, the level of project definition may not enable certain costs to be estimated definitively. There are also times when it is simply not cost-effective to quantify and cost every small item included with the project. To account for these situations, an allowance for the costs associated with these items may be included in the estimate.

Allowances are often included in the estimate as a percentage of some detailed cost component. Some typical examples of allowances that may be included in a detailed construction estimate are:

- ✓ Design allowance for engineering equipment
- ✓ Material take-off allowance
- ✓ Overbuy allowance
- ✓ Unrecoverable shipping damage allowance
- ✓ Allowance for undefined major items

The specific allowances and values will usually depend on specific organization estimating procedures and experience [S&K 6th Ed., 115].

3. Reserve

- An amount added to an estimate to allow for discretionary management purposes outside of the defined scope of the project, as otherwise estimated. Use of management reserve requires a change to the project scope and the cost baseline, while the use of contingency reserve funds is within the project's approved budget and schedule baseline [RP10S-90].

b. **Pricing** [Review S&K 6th Edition, Chapter 2, for more detailed discussion on this topic].

1. Cost vs. Pricing: be able to explain the difference

- **Cost**
 - ✓ In project control and accounting, it is the amount measured in money, cash expended or liability incurred, in consideration of goods and/or services

received. From a total cost management perspective, cost may include an investment of resources in strategic assets including time, monetary, human, and physical resources [RP10S-90].

- **Price**

- ✓ The amount of money asked or given for a product (e.g., exchange value). The chief function of price is rationing the existing supply among prospective buyers [RP10S-90].

2. Price Strategy:

Pricing Strategies must be developed for each individual situation. Essentially two situations frequently appear when one is pursuing a project. In each case, there are specific but different business objectives [S&K 6th Ed., 22].

Type I Situation The objective is to win the project and execute it profitably and satisfactorily according to contractual agreements.

Type II Situation is an example of a “must win” situation where the price is determined by the market forces. This case refers to a company that is trying to get a foothold into an industry. In such cases the profit may not be as important as obtaining the new business acquisition.

- **Pricing** – Method adopted by a firm to set its selling price. It usually depends on the firm’s average costs, and on the customer’s perceived value of the product in comparison to his or her perceived value of the competing products. Different pricing methods place varying degree of emphasis on selection, estimation, and evaluation of costs, comparative analysis, and market situation [Business Dictionary.com].
- **Pricing Strategy** – Price planning that takes into view factors such as a firm’s overall marketing objectives, consumer demand, product attributes, competitor’s pricing, and market and economic trends [Business Dictionary.com].
- **Market Pricing** – Worth of a job based on the current (going) compensation rate for comparable benchmark jobs in the labor market [Business Dictionary.com].
- **Market Penetration Pricing** – Strategy adopted for quick achieving a high volume of sales and deep market-penetration of a new product. Under this approach, a product is widely promoted and its introductory-price is kept comparatively lower. This strategy is based on the assumption that (1) the product does not have an identifiable price-market segment, (2) it has elasticity of demand (buyers are price sensitive), (3) the market is large enough to sustain relatively low profit margins, and (4) the competitors too will soon lower their prices [Business Dictionary.com].
- **Demand-Oriented Pricing** – Method in which price of a product is changed according to its demand higher price when the demand is strong, lower price when it is weak [Business Dictionary.com].
- **Predatory Pricing** – Practice of temporarily selling below survival prices or giving goods away to undermine or eliminate the existing competition. Predatory pricing is an abuse of dominant position, and is illegal in several countries [Business Dictionary.com].

- **At Cost Pricing** – In slow construction cycles, contractors often price jobs at or just below cost to keep their workforce employed and active in the market. However, contracts awarded in this case often suffer from extensive change order requests to make the project profitable.
- c. **Estimating** [Review S&K 6th Edition, Chapter 9, for more detailed discussion on this topic].

1. Definition of a Cost Estimate

- A cost estimate is defined as “a compilation of all the costs of the elements of a project or effort included within an agreed upon scope.” To a contractor, this is the cost that will most likely be incurred in completing the project as defined in the contract documents. The contractor’s cost includes its own internal costs, as well as those of its subcontractors, suppliers, and third parties [S&K 6th Ed., Chap 9].
- A predictive process used to quantify, cost, and price the resources required by the scope of an asset investment option, activity, or project. As a predictive process, estimating must address risks and uncertainties. The outputs of estimating are used primarily as inputs for budgeting, cost or value analysis, decision making in business, asset and project planning, or for project cost and schedule control processes [RP10S-90].

2. Basic Steps of Estimating

- **Take-Off**
 - ✓ Measuring and cataloging the quantities of work derived from the scope documents [S&K 6th Ed., Chap 9, 112].
- **Costing**
 - ✓ Using the take-off and the information presented in the scope documents to assign cost values to the elements of work previously cataloged [S&K 6th Ed., Chap 9, 113].
- **Pricing**
 - ✓ Determining the amount to be charged to the owner/client so as to fully include direct and indirect cost items, as well as contingency and profit [S&K 6th Ed., Chap 9, 113].

3. Basic Cost Estimating Terminology

- **Addendum (Addenda)**
 - ✓ A written change or graphic instrument issued before the date bids are opened. An addendum may interpret or modify the bidding documents by making additions, deletions, clarifications, or corrections [RP10S-90].
- **Allowances**
 - ✓ Additional resources included in estimates to cover the cost of known but undefined requirements for an individual activity, work item, account, or subaccount [S&K 6th Ed., Chap 9, 115; RP10S-90].
- **Alternate**

- ✓ A request from the owner for the cost of adding or deleting an item or work element from the basic bid. The cost of adding an item is usually known as an additive alternate, while the cost of deleting an item is known as a deductive alternate [S&K 4th Ed., 1-2].
- **Bid Documents**
 - ✓ The advertisement for bids, instructions to bidders, information available to bidders, bid form with all attachments, and proposed contract documents (including all addenda issued before the receipt of bids) [S&K 4th Ed., 1-2].
- **Change Order**
 - ✓ A document requesting a change or correction; a written change made by the architect / engineer to the contract drawings and/or specifications after the contract award. Generally, a change order must be approved by the owner/client and the contractor before it becomes a legal change to contract [RP10S-90].
- **Contingency**
 - ✓ An amount added to the estimate to allow for changes that experience shows will likely be required. This may be derived through statistical analysis of past-project cost or by applying experience gained on similar projects. Contingency usually does not include changes in scope or unforeseeable major events such as strikes or earthquakes [S&K 6th Ed., Chap 9].
 - ✓ An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs. Typically estimated using statistical analysis or judgment based on past asset or project experience. Contingency usually excludes: 1) Major scope changes such as changes in end product specification, capacities, building size, and location of the asset or project. 2) Extraordinary events such as major strikes and natural disasters; 3) Management reserves; and 4) Escalation and currency effects. Some of these items, conditions, or events for which the state, occurrence, and/or effect is uncertain include, but are not limited to, planning and estimating errors and omissions, minor price fluctuations (other than general escalation), design developments and changes within the scope, and variations in market and environmental conditions. Contingency is generally included in most estimates, and is expected to be expended [RP10S-90].
- **Contract Documents**
 - ✓ The contract forms, general and specific conditions, drawings, specifications, and addenda describing the project scope and contract terms [S&K 6th Ed., Chap 9, 110].
- **Cost**
 - ✓ The amount a contract item is known or estimated to cost the contractor [S&K 6th Ed., Chap 9].
- **Cost Index**

- ✓ A number that relates the cost of an item at a specific time to the corresponding cost at some arbitrarily specified time in the past. A cost index is useful in taking known past costs for an item and relating them to the present. [S&K 6th Ed., Section2].
- **Direct Cost**
 - ✓ Costs that can be directly attributed to a particular item of work or activity [S&K 6th Ed., Chap 1, p 11].
 - ✓ Costs of completing work that is directly attributable to its performance and are necessary for its completion. In construction: the cost of installed equipment, material, labor and supervision directly or immediately involved in the physical construction of the permanent facility [RP10S-90].
- **Distributable Cost**
 - ✓ A cost item that is spread over other cost items rather than managed as a separate account [S&K 4th Ed., 1-2].
- **Escalation**
 - ✓ Provision for an increase in the cost of equipment, material, labor, etc, over the costs specified in the contract, due to continuing price-level changes over time [S&K 6th Ed., Chapters 7, 9, & 10].
 - ✓ The provision in actual or estimated costs for an increase in the cost of equipment, material, labor, etc., over that specified in the purchase order or contract resulting from continuing price level changes over time. Inflation may be a component of escalation, but non-monetary policy influences, such as supply-and-demand, are often components [RP10S-90].
- **Field Costs**
 - ✓ Indirect costs of engineering and construction associated with the project's field site rather than with the home office [S&K 6th Ed., Chap 9; RP10S-90].
- **General Conditions**
 - ✓ A specific portion of the contract documents. They state the responsibilities and relationships of all parties to the contract, as well as any conditions applicable to the contract [S&K 6th Ed., Chap 2].
- **Indirect Costs**
 - ✓ In construction, all costs that do not become a final part of the installation. They include, but are not limited to, field administration, direct supervision, capital tools, start-up costs, contractor's fees, insurance, and taxes [S&K 6th Ed., Chap 1, p 11; RP10S-90].
- **Labor Burden**
 - ✓ Taxes and insurance costs based on labor payroll that the employer is legally required to pay on behalf of or for the benefit of laborers. (In the US, these include federal old age benefits, federal unemployment insurance tax, state unemployment insurance tax, and workers' compensation) [RP10S-90].
- **Labor Cost**
 - ✓ The base salary, plus all fringe benefit costs and labor burdens associated with labor, that can e definitely assigned to one item of work, product, process area, or cost center [S&K 6th Ed., Chap 4].

- a) **Bare Labor**- Gross direct wages paid to the worker.
- b) **Burdened Labor** – Gross direct wages paid to the worker, plus labor burden.
- c) **All In Labor** – Burdened Labor plus general & administrative cost, plus profit [RP10s-90].

- **Mark-Up**

- ✓ As variously used in construction estimating, such percentage applications as general overhead, profit, and other indirect costs. When mark-up is applied to the bottom of a bid sheet for a particular item, system, or other construction price, any or all of the above items (or more) may be included, depending on local practice [S&K 6th Ed., Chap 11; RP10S-90].

- **Overhead**

- ✓ A cost or expense inherent in performing an operational, i.e., engineering, construction, operating, or manufacturing, that cannot be charged to or identified with a part of the work, product, or asset and which, therefore, must either be allocated on some arbitrary basis believed to be equitable, or handled as a business expense independent of the volume of production [S&K 6th Ed., Chap 1; RP10S-90].

- **Price**

- ✓ The amount of money asked or given for a product (i.e., the exchange value). The chief function of price is to ration the existing supply among prospective buyers. Price incorporates direct costs, indirect costs, general overhead, profit, and contingency [S&K 6th Ed., Chap 2].
- ✓ The amount of money asked or given for a product. The chief function of price is rationing the existing supply among prospective buyers [RP10S-90].

- **Productivity**

- ✓ A relative measure of labor efficiency, either good or bad, when compared to an established base or norm as determined from an area of great experience. Alternatively, productivity is defined as the reciprocal of the labor factor [S&K 6th Ed., Chap 4].
- ✓ A measure of output relative to input. Productivity is improved by increasing output for a given input, or decreasing input for a given output. If the input is specifically work hours, the term commonly used is labor productivity [RP10S-90].

- **Scope**

- ✓ The equipment and materials to be provided, and the work to be done. Scope is documented by the contract parameters for a project to which the company is committed [S&K 6th Ed., Chap 2].

- **Special Conditions**

- ✓ Modifications to the general conditions. Special conditions are applicable and unique to a specific project [S&K 6th Ed., Chap 12].

- **Time- Sensitive**

- ✓ A term applied to those elements of cost that will be expended or incurred on a time-unit basis (monthly, weekly, hourly, etc.) and that are a subset of indirect

costs. A cost engineer's salary on a project is a time-sensitive cost as long as that engineer is on the project [S&K 4th Ed., 1-2].

- **Value Engineering**

- ✓ A practice function that is targeted at the design itself. The objective of value engineering is to develop or design a facility or item that will yield the least life-cycle costs or provide the greatest value while satisfying all performance and other criteria established for it [S&K 6th Ed., Chap 22].

4. Types of Estimates

There are numerous characteristics that can be used to categorize cost estimate types. The most significant characteristics are degree of project definition, end usage of the estimate, estimate methodology, as well as the effort and time needed to prepare the estimate [S&K 6th Ed., Chap 9].

The Most Commonly Used Estimates

- **Order-of-Magnitude Estimates**

- ✓ Estimates made without detailed engineering data. An estimate of this type would normally be expected to be accurate within +50 percent or – 30 percent. Order-of-magnitude estimates are sometimes referred to as “conceptual” or “ballpark” estimates. They have a wide range of accuracy, and have important applications, such as using them to determine the feasibility of a project quickly or to screen several types of alternative designs. Order-of-magnitude estimates are generally prepared using only basic criteria such as desired output, total square meters, or number of units [S&K 6th Ed., Chap 10].

- **Budget Estimates**

- ✓ Budget estimates are prepared with the help of flow sheets, layouts, and equipment details. In other words, enough preliminary engineering has taken place to further define the project scope. An estimate of this type is normally expected to be accurate within +30 percent or -15 percent. Since the budget estimate is more definitive than the order-of-magnitude estimate, it is better suited for determining project feasibility and establishing definitive budget. The accuracy and usefulness of a budget estimate depends, to a large extent, on the amount and quality of information available [S&K 6th Ed., Chap 9].

- **Definitive Estimates**

- ✓ As the name implies, these are estimates prepared from very defined engineering data. The definitive estimate includes various degrees of detail estimates which could be made from “approved for construction” drawings and specifications. Definitive estimates are also called “check” lump sum, “tender,” and “post-contract change estimates. An estimate of this type is usually expected to be accurate within +15 percent or – 5 percent [S&K 6th Ed., Chap 23].

5. Estimate Classifications

There are numerous characteristics that can be used to categorize cost estimates types. The most significant of these are degree of project definition, end usage of the estimate, estimating methodology, and the effort and time needed to prepare the estimate. The “primary” characteristic used in this guideline to define the classification category is the degree of project definition. The other characteristics are “secondary” [RP17R-97].

The discrete levels of project definition used for classifying estimates correspond to the typical phases and gates of evaluation, authorization, and execution often used by project stakeholders during a project life cycle [RP17R-97].

Five cost estimate classes have been established. The estimate class designations are labeled Class 1, 2, 3, 4, and 5. A Class 5 estimate is based upon the lowest level of project definition, and a Class 1 estimate is closest to full project definition and maturity [RP17R-97].

- Class 5- 0% to 2% Level of Project Definition; Screening End Usage
- Class 4 -1% to 15% Level of Project Definition; Concept Study End Usage
- Class 3 - 10% to 40% Level of Project Definition; Budget End Usage
- Class 2 - 30% to 70% Level of Project Definition; Control or Bid End Usage
- Class 1 – 50% to 100% Level of Project Definition; Check or Bid End Usage
[RP17R-97]

6. Basis of Estimate

The Basis of Estimate (BOE) is characterized as the one deliverable that defines the scope of the project, and ultimately becomes the basis for change management. When prepared correctly, any person with capital project experience can use the BOE to understand and assess the estimate, independent of any other supporting documentation. A well-written BOE achieves those goals by clearly and concisely stating the purpose of the estimate being prepared (i.e., cost study, project options, funding, etc), the project scope, pricing basis, allowances, assumptions, exclusions, cost risks and opportunities, and any deviations from standard practices. In addition the BOE is a documented record of pertinent communications that have occurred and agreements that have been made between the estimator and other project stakeholders [RP34R-05].

The following describes some of the suggested topics and contents included in a typical BOE

- **Purpose**
 - ✓ In this initial section of the BOE, the estimator should provide a brief and concise description for the total project. The type of project should be identified (i.e., new facilities, addition to existing, revamp of existing, etc.), as well as the type and capacity of the process units, the location of the facility, and the overall timing of the project [RP 34R-05].
- **Project Scope Description**
 - ✓ This section of the estimate basis should be organized to correspond with the project's work breakdown structure (i.e., plant, building, floor, etc.). A semi-detailed description of the scope of work should be provided for each major segment of the project. Identify any major pieces of process equipment or components. It's also good practice to indicate the primary trades that will be involved with the project [RP 34R-05].
- **Methodology**
 - ✓ The BOE should indicate the primary estimating methodology used to prepare the cost estimate. This should include documentation of the use of cost resources, historical data and project benchmarking [RP 34R-05].

- **Estimate Classification**
 - ✓ The AACE International estimate classification should be identified, along with reasons or justification used in the selection of the estimate classification [RP 34-05].

- **Assumptions**
 - ✓ Any other assumptions made by the estimator but not documented elsewhere in the estimate basis should be included in this section [RP 34-05].

- **Exclusions**
 - ✓ In this section, the estimator should document all potential items of cost which a reviewer might associate with the project, but for which no costs have been included in the estimate [RP 34-05].

- **Cost Basis**
 - ✓ Describe the methods and sources used for determining all material, labor and subcontractor pricing [RP 34-05].

- **Exceptions**
 - ✓ The estimator should identify any anomalies or variances to your organization's standard estimating practices [RP 34-05].

- **Risk and Opportunities**
 - ✓ Any areas of the estimate containing significant risk or opportunity should be identified [RP 34-05].

- **Contingency**
 - ✓ Explain the method used to develop contingency and the rates that were applied. Contingency often can be the largest single line item in an estimate, and it deserves special attention [RP 34-05].

- **Management Reserve**
 - ✓ Contingency is not intended to cover the costs associated with changes in project scope [RP 34-05].

- **Reconciliation**
 - ✓ Provide an overview of the major differences between the current estimate and the last published estimate prepared for this project [RP 34-05].

- **Benchmarking**
 - ✓ This section should document any comparisons of overall estimate metrics, ratios, and factors with similar projects, historical data, and industry data [RP 34-05].

- **Estimate Quality Assurance**
 - ✓ Since estimate reviews are the means for testing the quality of the estimate, this section of the BOE should identify all estimate reviews that have taken place to date, and any additional reviews that are proposed to take place [RP 34-05].

- **Estimating Team**

- ✓ In this final section, all members of the estimating team should be identified, including roles and responsibilities [RP 34-05].

[Refer to Recommended Practice 34R-05 and S&K 6th Edition, Section 2, for more detailed discussion on this topic].

Because cost estimates are approximations based in varying degree upon assumptions and interpretations of scope, plans, and objectives, stakeholders often misunderstand what a cost estimate represents. Communicating the basis of an estimate reduces misunderstanding, error, and misuse. In general, the estimate basis (and all estimate backup) becomes the one deliverable that defines the scope of the project. As such, the estimate basis is also the basis for change management [TCM Framework, 7.3.4].

7. Direct and Indirect Cost in Estimating

Estimates must segregate direct and indirect costs. Many estimates are based on historical database compiled from cost data derived from previous projects. The less that the direct cost data is encumbered with indirect costs, the more reliable the direct cost data will be for use on the new project. Keeping indirects separate allows the unique conditions that will be encountered in the new project to be more accurately reflected in the estimate [S&K 6th Ed., Section 2].

- **Direct Costs**

- ✓ Labor costs (base wage, fringe benefits, labor burden).
- ✓ Material costs.
- ✓ Equipment costs (equipment used to perform a contract, not equipment installed permanently).
- ✓ Subcontract costs.

- **Indirect Costs**

- ✓ **Taxes.**
- ✓ **Profit-** The amount of money included by a contractor in its price as compensation for risk, efforts, and endeavor in undertaking a project.
- ✓ **Contingency** – An amount added to an estimate to allow for changes or project cost growth that experience shows will likely be required.
- ✓ **Home Office Overhead** – the fixed costs and expenses incurred in the course of doing business, regardless of the amount of work completed or contracts received.

- a) Salaries (home office)
- b) Employee benefits
- c) Professional fees
- d) Insurance
- e) Office lease or rent
- f) Office stationary and supplies
- g) Depreciation
- h) Maintenance
- i) Procurement and marketing
- j) Home office travel and entertainment
- k) Advertising

- ✓ **Job Site Overhead** – provisions contained in a contract, purchase order, or specification that are not specific to the particular transaction but which apply to all transactions.

- a) Bonds
- b) Permits
- c) Mobilization
- d) Professional services
- e) Safety equipment
- f) Small tools
- g) Supervision
- h) Temporary facilities
- i) Travel and lodging
- j) Miscellaneous costs
- k) Demobilization

- ✓ **Escalation** – an increase in the cost of goods and services over time.

8. Estimate Structure

The control structure for a project is the breakdown of the total work into manageable units or packages for the purpose of estimating and control of cost and schedule. The proper structuring of a project for control purposes contributes greatly to the effective implementation of project control procedures and the success of the project itself [S&K 6th Ed., Chapter 9].

Large projects will often use work breakdown structures (WBS) and resource breakdown structures (RBS) as components of the overall coding structure. Smaller projects will often use a simpler code of accounts based simply on the disciplines or construction trades used on the project [S&K 6th Ed., Chapter 9].

The WBS and RBS are basic project management tools that define the project along activity levels that can be clearly identified, managed, and controlled [S&K 6th Ed., Chapter 9].

Other estimate formats may include CSI breakdown, UNIFORMAT (Building Systems) breakdown or bid packages.

9. Factored Estimates

- **Capacity Factored Method**

- ✓ A capacity factored estimate is one in which the cost of a new facility is derived from the cost of a similar facility of a known (but usually different) capacity. It relies on the nonlinear relationship between capacity and cost [S&K 6th Ed., Chapter 9].

- **Ratio or Factored Methods**

- ✓ Ratio or factored estimating methods are used in situations where the total cost of an item or facility can be reliably estimated from the cost of a primary component. This is often referred to as “equipment factor” estimating [S&K 6th Ed., Chapter 9].

10. Pricing the Estimate

- Price includes charging techniques that various stakeholders in the plan (bidders, contractors, etc.) apply to costs in the estimate to allow for overhead and profit, to improve cash flow, or to otherwise address market conditions and serve their

business interests. It is important to distinguish between costs and prices. For example, contractors often unbalance a bid estimate by allocating costs to those items for which payment will be obtained early in a project; therefore, contract bid prices may not be a very useful reference source for developing a cost database [TCM Framework].

11. Estimate Review and Validation

- Because an estimate is of critical importance to a project's success, it makes sense that the estimate should undergo a rigorous review process. The estimate should be evaluated not only for its quality or accuracy, but also to ensure that it contains all the required information and is presented in a way that is understandable to all project team members and client personnel [S&K 6th Ed., Chapter 9].
- Cost estimates typically represent a complex compilation and analysis of input from many project stakeholders. To ensure the quality of an estimate, budget or bid, a review process is required to ensure that the estimate meets project and organization requirements. The project plan typically requires that the cost estimate:
 - ✓ Reflect the project strategy, objectives, scope and risks.
 - ✓ Be suitable for a given purpose (e.g., cost analysis, decision making, control, and bidding. Etc.).
 - ✓ Address the stakeholders financial and performance requirements.
 - ✓ Ensure that all parties agree on and understand the estimate's basis, content and outcome, including the estimate's probabilistic characteristics (e.g., range, cost distribution, etc.) [RP31R-03].
- An estimate should include the following type of Review Cycle
 - ✓ Technical (Engineering/Design)/Scope Reviews.
 - ✓ Estimating Team Reviews.
 - ✓ Project Manager/Project Team Reviews.
 - ✓ Management Reviews [RP 31R-03].

2. Elements of Analysis

a. Statistics and Probability

1. Samples and Populations:

Statistics is the field of study where data are collected for the purpose of drawing conclusions and making inferences. Descriptive statistics is the summarization and description of data, and inferential statistics is the estimation, prediction, and or generalization about the population based on the data from a sample [S&K 6th Ed., Chap 9].

Statistics is concerned with scientific methods for collecting, organizing, summarizing, presenting, and analyzing data as well as with drawing valid conclusions and making reasonable decisions on the basis of such analysis [Schaum's Statistics Crash Course].

The conclusions based upon the statically analysis are useful in the development of a "business case" or to justify decision to proceed with a project or not.

Four elements are essential to inferential statistical problems:

- Population is the collection of all elements of interest to the decision-maker. The size of the population is usually denoted by N . Very often, the population is so large that a complete census is out of the question. Sometimes, not even a small population can be examined entirely because it may be destructive or prohibitively expensive to obtain the data. Under these situations, we draw inferences based upon a part of the population (called a sample) [S&K 6th Ed., Chap 29].
- Sample is a subset of data randomly selected from a population. The size of a sample is usually denoted by n [S&K 6th Ed., Chap 29].
- Statistical inference is an estimation, prediction or generalization about the population based on the information from the sample [S&K 6th Ed., Chap 29].
- Reliability is the measurement of the “goodness” of the inference [S&K 6th Ed., Chap 29].

2. Descriptive Statistics

1. Basic Statistics:

- **Mean (average)**

- ✓ Mean is the sum of measurements divided by the number of measurements [S&K 6th Ed., Chap 29].
- ✓ The best known and most reliable measure of central tendency is the mean. The mean is the arithmetic average of a group of scores [S&K 6th Ed., Chap 29].

- **Median**

- ✓ Median is the middle number when the data observations are arranged in ascending or descending order. If the number n of measurements is even, the median is the average of the two middle measurements in the ranking [S&K 6th Ed., Chap 29].
- ✓ The median is the middle point in a distribution. Half of the distribution is above this point and half is below. To find the median one arranges the scores in order [S&K 6th Ed., Chap 29].
- ✓ The median of a set of numbers arranged in order of magnitude (i.e., in an array) is either the middle value (if the number of data values is odd) or the arithmetic mean of the two middle values (if the number of data values is even) [Schaum’s Statistics Crash Course, Murray R. Spiegel].
- ✓ In a population or a sample, the median is the value that has just as many values above it as below it. If there is an even number of values, the median is the average of the two middle values. The median is a measure of central tendency. The median can also be defined as the 50th percentile. For symmetrical distributions the median coincides with the mean and the center of the distribution. For this reason, the median of a sample is often used as an estimator of the center of the distribution. If the distribution has heavier tails than the normal distribution, then the sample median is usually a more precise estimator of the distribution center than the sample mean [Statistics.com 2004-2010].

- ✓ The median of a set of data is a value that divides the bottom 50 percent of the data from the top 50 percent of the data. To find the median of a data set, first arrange the data in increasing order. If the number of observations is odd, the median is the number in the middle of the ordered list. If the number of observations is even, the median is the mean of the two values closest to the middle of the ordered list [Schaum's Beginning Statistics 2nd Edition, Larry J. Stephens, Ph.D.].
- **Mode**
 - ✓ Mode is the measurement that occurs most often in the data set. If the observations have two modes, the data set is said to have a bimodal distribution. When the data set is multi-modal, the mode(s) is no longer a viable measure of the central tendency. In a large data set, the modal class is the class containing the largest frequency. The simplest way to define the mode will then be the midpoint of the modal class [S&K 6th Ed., Chap 29].
 - ✓ The mode is the simplest measure of central tendency. It is merely the score value or measure that occurs most often in a distribution of scores [S&K 6th Ed., Chap 29].
 - ✓ The mode of a set of numbers is that value which occurs with the greatest frequency: that is, it is the most common value. The mode may not exist, and even if it does exist it may not be unique [Schaum's Statistics Crash Course, Murray R. Spiegel].
 - ✓ The mode is a value that occurs with the greatest frequency in a population or a sample. It could be considered as the single value most typical of all the values [Statistics.com 2004-2010].
- **Range**
 - ✓ The range is defined as the difference between the lowest and highest score in a distribution of scores. The range is not considered a stable measurement of variability because the value can change greatly with the change in a single score within the distribution – either the high or low score [S&K 6th Ed., Chap 29].
 - ✓ The difference between the largest and the smallest values of the data set. The range only uses the two extreme values and ignores the rest of the data set [S&K 6th Ed., Chap 29].
 - ✓ The range for a data set is equal to the maximum value in the data set minus the minimum value in the data set. It is clear that the range is reflective of the spread in the data set since the difference between the largest and the smallest values is directly related to the spread in the data [Schaum's Beginning Statistics 2nd Edition, Larry J. Stephens, Ph.D.].
- **Quartile Deviation**
 - ✓ The quartile deviation is more stable than the range because it is based on the spread of the scores through the center of the distribution rather than through the two extremes. Since the quartile deviation is an index that reflects the spread of scores throughout the middle part of the distribution, it should be used whenever extreme scores may distort the data. Thus, the median and the quartile deviation are both insensitive to extreme scores in the distribution and

should be used accordingly. The major disadvantage of the quartile deviation is that it does not take into account the value of each of the raw scores in the distribution [S&K 6th Ed., Chap 29].

- **Standard Deviation**

- ✓ Is a more reliable indicator of the spread of a distribution. It determines the amount each score deviates from the mean of the distribution [S&K 5th Ed., 30.6].
- ✓ The positive square root of the variance [S&K 6th Ed., Chap 29].
- ✓ The standard deviation is a measure of dispersion. It is the positive square root of the variance. An advantage of the standard deviation (as compared to the variance) is that it expresses dispersion in the same units as the original values in the sample or population. For example, the standard deviation of a series of measurements of temperature is measured in degrees; the variance of the same set of values is measured in “degrees squared” [Statistics.com 2002-2010].

- **Variance**

- ✓ The average of the squared deviations from the mean. The variance has a squared unit and is in a much larger scale than that of the original data [S&K 6th Ed., Chap 29].
- ✓ Variance is a measure of dispersion. It is the average squared distance between the mean and each item in the population or in the sample. An advantage of variance (as compared to the related measure of dispersion – the standard deviation) is that the variance of a sum of independent random variables is equal to the sum of their variances [Statistics.com 2004-2010].

- **Normal Distribution:** [Review S&K 6th Edition, Chapter 29, for more detailed discussion on this topic].

- **Normal Distribution**

- ✓ One of the most important examples of a continuous probability distribution is the normal distribution. Normal curve or Gaussian distribution [Schaum’s Statistics Crash Course, Murray R. Spiegel].
- ✓ The normal distribution is a probability density which is bell-shaped, symmetrical, and single peaked. The mean, median and mode coincide and lie at the center of the distribution. The two tails extend indefinitely and never touch the X- axis (asymptotic to the X-axis). A normal distribution is fully specified by two parameters – mean and the standard deviation [Statistics.com 2004-2010].
- ✓ The most important continuous distribution in statistical decision making is the normal distribution. A graph of a normal distribution is called a normal curve and it has the following characteristics”
 - a. It is bell-shaped and is symmetrical about the mean. The mean, median and mode are all equal. Probability density decreases symmetrically as X values move from the mean in either direction.
 - b. The curve approaches but never touches the horizontal axis. However, when the value of X is more than three standard deviations from the

mean, the curve approaches the axis so closely that the extended area under the curve is negligible [S&K 6th Ed., Chap 29].

- **Normal Probability Distribution**

- ✓ The most important and widely used of all continuous distributions is the normal probability distribution. The larger the standard deviation, the more disperse are the values about the mean [Schaum's Beginning Statistics 2nd Edition, Larry J. Stephens, Ph.D.].

- **Standard Normal Distribution**

- ✓ The standard normal distribution is the normal distribution having mean equal to 0 and standard deviation equal to 1 [Schaum's Beginning Statistics 2nd Edition, Larry J. Stephens, Ph.D.].

2. **Non-Normal Distributions:** be able to describe the following concepts:

a. **Skewness**

- ✓ A symmetric histogram in which each class has the same frequency is called a uniform or rectangular histogram. A skewed to the right histogram has a longer tail on the right side. A skewed to the left histogram has a longer tail on the left side [Schaum's Beginning Statistics 2nd Edition, Larry J. Stephens, Ph.D.].
- ✓ The reason for constructing histograms and frequency polygons is to reveal how scores are distributed along the score scale. That is, the form of the distribution is shown. A distribution is symmetrical if one side is a mirror image of the other. If not, it is asymmetrical. Asymmetrical curves can be skewed either positively or negatively. For negative skewness, the tail travels to the left, for positive skewness, the tail travels to the right.
- ✓ Skewness measures the lack of symmetry of a probability distribution. A curve is said to be skewed to the right (or positively skewed) if it tails off toward the high end of the scale (right tail longer than the left). A curve is skewed to the left (or negatively skewed) if it tails off toward the low end of the scale. Skewness of the distribution whose density is symmetrical around the mean is zero. The reverse is not true – there are asymmetrical distributions with zero skewness. Skewness characterizes the shape of a distribution – that is, its value does not depend on an arbitrary change of the scale and location of the distribution. For example, skewness of a sample (or population) of temperature values in Fahrenheit will not change if you transform the values to Celsius (the mean and the variance will, however, change) [Statistics.com 2004-2010].

b. **Kurtosis**

- ✓ Kurtosis measures the "heaviness of the tails" of a distribution (in compared to a normal distribution). Kurtosis is positive if the tails are "heavier" than for a normal distribution and negative if the tails are "lighter" than for a normal distribution. The normal distribution has kurtosis of zero [Statistics.com 2004-2010].

3. **Histograms, Cumulative Frequency:**

- **Histograms**

- ✓ A histogram is a graph that displays the classes on the horizontal axis and the frequencies of the classes on the vertical axis. The frequency of each class is represented by a vertical bar whose height is equal to the frequency of the class. A histogram is similar to a bar graph. However, a histogram uses classes or intervals and frequencies while a bar graph uses categories and frequencies [Schaum's Beginning Statistics 2nd Edition, Larry J. Stephens, Ph.D.].
- ✓ In a histogram, the frequency of each score or class is represented as a vertical bar. When developing the histogram, the $\frac{3}{4}$ rule should be applied. That is, the highest frequency should be laid out so that the height is approximately $\frac{3}{4}$ the length of the horizontal axis. Otherwise, the viewer may obtain the wrong impression based on graph appearance rather than on graph data. The bar width should be the same as the "real limit" of a class. In addition, the graph should be titled in a descriptive fashion to indicate what the graph is showing [S&K 6th Ed., Chap 21 & 29].
- ✓ Histograms and frequency polygons are two graphic representations of frequency distributions. A histogram or frequency histogram, consists of a set of rectangles having (a) bases on a horizontal axis (the X axis), with centers at the class marks and lengths equal to the class interval sizes, and (b) areas proportional to the class frequencies [Schaum's Statistics Crash Course, Murray R. Spiegel].

3. Inferential Statistics

1. **Probability:**

- ✓ Probability is a measure of the likelihood of the occurrence of some event [Schaum's Beginning Statistics 2nd Edition, Larry J. Stephens, Ph.D.].

Hint: Given a curve of normal distribution and an accompanying table of areas under the curve, be able to determine the probability of:

- a) The variable being between two given numbers.
- b) Not being higher than a given number, or lower than that number.
- c) Given a confidence interval or range in terms of percentage probability, give the corresponding low and high number of the interval or range.

2. **Regression Analysis:**

- ✓ Regression analysis provides a "best-fit" mathematical equation for the relationship between the dependent variable (response) and independent variable(s). There are two major classes of regression – parametric and non-parametric. Parametric regression requires choice of the regression equation with one or a greater number of unknown parameters. Linear regression, in which a linear relationship between the dependent variable and independent variables is posited, is an example. The aim of parametric regression is to find the values of these parameters which provide the best fit to the data. The number of parameters is usually much smaller than the number of data points [Statistics.com 2004-2010].

3. **Statistical Significance:**

a. **Chi-squared**

- ✓ The chi-square test can be used to determine how well theoretical distributions (such as the normal and binomial distributions) fit empirical distributions (i.e., those obtained from sample data) [Schaum's Statistic Crash Course, Murray R. Spiegel].
- ✓ Chi-squared test is a statistical test for testing the null hypothesis that the distribution of a discrete random variable coincides with a given distribution. It is one of the most popular goodness-of-fit tests. For small samples, the classical chi-squared test is not very accurate – because the sampling distribution of the statistic of the test differs from the chi-square distribution. In such cases, Monte Carlo simulation is a more reasonable approach [Statistics.com 2004-2010].

b. **T-tests**

- ✓ A t-test is a statistical hypothesis test based on a test statistic whose sampling distribution is a t-distribution. Various t-tests, strictly speaking, are aimed at testing hypotheses about populations with normal probability distribution. However, statistical research has shown that t-test often provide quite adequate results for non-normally distributed populations too. The term “t-test” is often used in a narrower sense – it refers to a popular test aimed at testing the hypothesis that the population mean is equal to some value [Statistics.com 2004-2010].

c. **T-statistic**

- ✓ T-statistic is a statistic whose sampling distribution is a t-distribution [Statistics.com 2004-2010].

Recommendation: Reference books, **Schaum's Beginning Statistics 2nd Edition**, Larry J. Stephens, Ph.D.; *Schaum's Statistics Crash Course*, Murray R. Spiegel. These books provide graphs, charts and sample problems for basis statistics.

b. **Economic and Financial Analysis**

1. **Economic Cost:**

- ✓ **Opportunity Cost** (of capital) The rate of return available on the next best available investment of comparable risk [RP 10S-90].

2. **Cash Flow Analysis:**

- Cash Flow
 - ✓ Inflow and outflow of funds within a project. A time-based record of income and expenditures, often presented graphically [RP10S-90].

Hint: be able to calculate simple and compound interest rates and solve interest problems using the basic single payments, uniform series, and gradient formulas.

Hint: given a set of cost and revenue forecasts calculate a cash flow for an asset investment option

3. **Internal Rate of Return:**

- The compound rate of interest that when used to discount study period costs and benefits of a project, will make their time- values equal [RP10S-90].

4. **Present/Future Value Analysis:**

- **Present Value**

- ✓ The value of a benefit or cost found by discounting future cash flows to the base time. Also, the system of compounding proposed investments, which involves discounting at a known interest rate (representing a cost of capital or a minimum acceptable rate of return) in order to choose the alternative having the highest present value per unit of investment. This technique eliminates the occasional difficulty with profitability index of multiple solutions, but has the troublesome problem of choosing or calculating a “cost of capital” or minimum rate of return [RP10S-90].

- **Future Value**

- ✓ The value of a benefit or a cost at some point in the future, considering the time value of money [RP10S-90].

c. **Optimization**

1. **Model:**

- An optimization model is used to find the best possible choice out of a set of alternatives. It may use the mathematical expression of a problem to maximize or minimize some function. The alternatives are frequently restricted by constraints on the values of the variables [Answers.com].

2. **Linear Programming:**

- Mathematical techniques for solving a general class of optimization problems through minimization (or maximization) of a linear function subject to linear constraints. For example, in blending aviation fuel, many grades of commercial gasoline may be available. Prices and octane ratings, as well as upper limits on capacities of input materials which can be used to produce various grades of fuel are given. The problem is to blend the various commercial gasolines in such a way that: 1) Cost will be minimized (profit will be maximized; 2) A specified optimum octane rating will be met; and 3) The need for additional storage capacity will be avoided [RP 10S-90].

3. **Simulation:**

- Application of a physical or mathematical model to observe and predict probable performance of the actual item or phenomenon to which it relates [RP10S-90].
 - ✓ **Modeling** – Creation of a physical representation or mathematical description of an object, system or problem that reflects the function or characteristics of the item involved. Model building may be viewed as both a science and an art. Cost estimate and CPM schedule development should be considered modeling practices and not exact representations of future costs, progress and outcomes [RP10S-90].
 - ✓ **Monte Carlo Method** – A simulation technique by which approximate evaluations are obtained in the solution of mathematical expressions so as to determine the range or optimum value. The technique consists of simulating an experiment or model to determine some probabilistic property of a model, system or population of objects or events by use of random sampling to the components of the model, system, objects, or events. The method can be applied to cost estimates and schedules when they are expressed as a model [RP10S-90].

4. **Sensitivity Analysis:**

- A test of the outcome of an analysis by altering one or more parameters from an initially assumed value [RP10S-90].

d. **Physical Measurements: Hint:**

- Be able to convert basic metric and imperial weight and dimensional measurements.
- Be able to convert temperature from Fahrenheit degrees to Celsius.
- Be able to convert square feet to square yards, square feet to cubic yards.
- Be able to convert square feet into square inches.
- Be able to convert gallons to liters.

[See Appendix B, SI Units, S&K 5th Ed., for conversion exercises].

3. Enabling Knowledge

a. **Enterprise in Society**

1. **Societal Values:**

- **Society**
 - ✓ The human environment in which the enterprise exists as defined by its economic, political, legal, and other attributes. Society's stakeholders are its citizens, including enterprises [TCM Framework, 11.1.1].
- **Social Values**
 - ✓ Economic costs consider that the value of money is relative to time, currency, and context, including the societal context; that is, an amount of money saved to benefit both the enterprise and society has a greater value than the same amount of money saved to benefit only the enterprise. All societal values must be considered in planning, measurement, and assessment [TCM Framework, 11.1.1].
- A challenge with considering societal values is in how to measure them. They tend to be highly subjective and differ between individuals, groups, cultures, locales, and so on. It is also difficult to determine who the stakeholders in society are for a given situation. Much of the work involves very complex valuation modeling. Some social scientists consider it nearly impossible to make an economic-based decision with any certainty that will maximize social welfare; however, enterprises are increasingly expected by society (politically, legally, or otherwise) to make the attempt [TCM Framework, 11.1.1].

2. **Decision Policy:**

- Definitive position of an organization on how investment or project decisions will be made. Establishes the basis for decision models. Provides a basis for consistent and appropriate decision making and defines authority and accountability within the organization. The term Policy could also be used [10S-90].

3. Ethics:

1. At all times each person in the enterprise must judge the means and the ends of a process against personal and societal values and rules of conduct. These values and rules of conduct are referred to as ethics. In judging, people and organizations must ask questions about the means and ends such as: Are they fair, respectful, responsible, honest, and honorable? Society sets the framework for this questioning, but individuals and organizations make the judgments and set the rules. Discussions of society values therefore often involve a discussion of ethics or ethical values. Most enterprises will have an ethics policy if none other concerning social values [TCM Framework, 11.1.2].
2. Business ethics is considered a management discipline because of the social responsibility movement that began in the 1960's. During the 1960's social awareness movements emphasized the expectations of businesses to use their influence to address social problems. People asserted that since businesses were making profits, it was also their responsibility to work to improve society. Many replaced the word stockholder with stakeholder, including employees, customers, suppliers, and the wider community [S&K 6th Ed., Chap 20].
3. One definition is that ethics is the science of judging specifically human ends and the relationship of means to those ends or the art of controlling means so that they will serve specifically human ends. In terms of business, ethics is concerned with the relationship of business goals and techniques to human ends [S&K 6th Ed., Chap 20].

AACE Canon of Ethics

(refer to the AACE International web page www.aacei.org for any updates)

The AACE member, to uphold and advance the honor and dignity of Cost Engineering and the Cost Management profession and in keeping with the high standards of ethical conduct will (1) be honest and impartial and will serve employer, clients, and the public with devotion; (2) strive to increase the competence and prestige of their profession; and (3) will apply knowledge and skill to advance human welfare.

I. Relations With the Public

A. Members will hold paramount the safety, health, and welfare of the public, including that of future generations.

B. Members will endeavor to extend public knowledge and appreciation of cost engineering and cost management and its achievements, and will oppose any untrue, unsupported, or exaggerated statements regarding cost engineering and cost management.

C. Members will be dignified and modest, ever upholding the honor and dignity of their profession, and will refrain from self-laudatory advertising.

D. Members will express an opinion on a cost engineering or cost management subject only when it is founded on adequate knowledge and honest conviction.

E. On cost engineering or cost management matters, members will issue no statements, criticisms, or arguments that are inspired or paid for by an interested party or parties, unless they preface their comments by identifying themselves, by disclosing the identities of the party

or parties on whose behalf they are speaking, and by revealing the existence of any pecuniary interest they may have in matters under discussion.

F. Members will approve or seal only those documents, reviewed or prepared by them, which are determined to be safe for public health and welfare in conformity with accepted cost engineering, cost management and economic standards.

G. Members whose judgment is overruled under circumstances where the safety, health, and welfare of the public are endangered shall inform their clients or employers of the possible consequences.

H. Members will work through professional societies to encourage and support others who follow these concepts.

I. Members will work only with those who follow these concepts.

J. Members shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, and testimony.

II. Relations With Employers and Clients

A. Members will act in all matters as a faithful agent or trustee for each employer or client.

B. Members will act fairly and justly toward vendors and contractors and will not accept any commissions or allowances from vendors or contractors, directly or indirectly.

C. Members will inform their employer or client of financial interest in any potential vendor or contractor, or in any invention, machine, or apparatus that is involved in a project or work for either employer or client. Members will not allow such interest to affect any decisions regarding cost engineering or cost management services that they may be called upon to perform.

D. When, as a result of their studies, members believe a project(s) will not be successful, or if their cost engineering and cost management or economic judgment is overruled, they shall so advise their employer or client.

E. Members will undertake only those cost engineering and cost management assignments for which they are qualified. Members will engage or advise their employers or clients to engage specialists whenever their employer's or client's interests are served best by such an arrangement. Members will cooperate fully with specialists so engaged.

F. Members shall treat information coming to them in the course of their assignments as confidential and shall not use such information as a means of making personal profit if such action is adverse to the interests of their clients, their employers, or the public.

1. Members will not disclose confidential information concerning the business affairs or technical processes of any present or former employer or client or bidder under evaluation, without consent, unless required by law.

2. Members shall not reveal confidential information or finding of any commission or board of which they are members, unless required by law.

3. Members shall not duplicate for others, without express permission of the client(s), designs, calculations, sketches, etc., supplied to them by clients.

4. Members shall not use confidential information coming to them in the course of their assignments as a means of making personal profit if such action is adverse to the interests of their clients, employers, or the public.

G. Members will not accept compensation—financial or otherwise—from more than one party for the same service, or for other services pertaining to the same work, without the consent of all interested parties.

H. Employed members will engage in supplementary employment or consulting practice only with the consent of their employer.

I. Members shall not use equipment, supplies, laboratory, or office facilities of their employers to carry on outside private practice without the consent of their employers.

J. Members shall not solicit a contract from a governmental body on which a principal officer or employee of their organization serves as a member.

K. The member shall act with fairness and justice to all parties when administering a construction (or other) contract.

L. Before undertaking work for others in which the member may make improvements, plans, designs, inventions, or records that may justify copyrights or patents, the member shall enter into a positive agreement regarding the rights of respective parties.

M. Members shall admit and accept their own errors when proven wrong and refrain from distorting or altering the facts to justify their decisions.

N. Members shall not attempt to attract an employee from another employer by false or misleading representations.

O. Members shall act in professional matters for each employer or client as faithful agents or trustees and shall avoid conflicts of interest.

1. Members shall avoid all known or potential conflicts of interest with their employers or clients and shall promptly inform their employers or clients of any business association, interests, or circumstances that could influence their judgment or the quality of their services.

2. Members shall not solicit or accept gratuities, directly or indirectly, from contractors, their agents, or other parties dealing with their clients or employers in connection with work for which they are responsible.

III. Relations With Other Professionals

A. Members will take care that credit for cost engineering and cost management work is given to those to whom credit is properly due.

B. Members will provide prospective employees with complete information on working conditions and their proposed status of employment. After employment begins, they will keep the employee informed of any changes in status and working conditions.

C. Members will uphold the principle of appropriate and adequate compensation for those engaged in cost engineering and cost management work, including those in subordinate capacities.

D. Members will endeavor to provide opportunity for the professional development and advancement of individuals in their employ or under their supervision.

E. Members will not attempt to supplant other cost engineers or cost management professionals in a particular employment after becoming aware that definite steps have been taken toward the others' employment or after they have been employed.

F. Members shall not maliciously or falsely, directly or indirectly, injure the professional reputation, prospects, practice, or employment of another, nor shall they indiscriminately criticize another's work. Proof that another cost professional has been unethical, illegal, or unfair in his/her practice shall be cause for advising the proper authority.

G. Members will not compete unfairly with other cost professionals.

H. Members will cooperate in advancing the cost engineering and cost management profession by interchanging information and experience with other cost professionals and students, by contributing to public communication media and to cost engineering, cost management and scientific societies and schools.

I. Members will not request, propose, or accept professional commissions on a contingent basis under circumstances that compromise their professional judgments.

J. Members will not falsify or permit misrepresentation of their own or their associates' academic or professional qualifications. They shall not misrepresent or exaggerate their degrees or responsibility in or for the subject matter of prior assignments. Brochures or other presentations incident to the solicitation of employment shall not misrepresent pertinent facts concerning employers, employees, associates, joint ventures, accomplishments, or membership in technical societies.

K. Members will prepare articles for the lay or technical press that are only factual, dignified, and free from ostentatious or laudatory implications. Such articles shall not imply credit to the cost professionals for other than their direct participation in the work described unless credit is given to others for their share of the work.

L. Members will not campaign, solicit support, or other wise coerce other cost professionals to support their candidacy or the candidacy of a colleague for elective office in a technical association.

IV. Standards of Professional Performance

A. Members shall be dignified and modest in explaining their work and merit and will avoid any act tending to promote their own interests at the expense of the integrity, honor, and dignity of the profession.

B. Members, when serving as expert witnesses, shall express a cost engineering and cost management opinion only when it is founded upon adequate knowledge of the facts, upon a background of technical competence, and upon honest conviction.

C. Members shall continue their professional development throughout their careers and shall provide opportunities for the professional development of those cost professionals under their supervision.

1. Members should keep current in their specialty fields by engaging in professional practice, participating in continuing education courses, reading in the technical literature, and attending professional meetings and seminars.

2. Members should encourage their cost engineering and cost management employees to become certified at the earliest possible date.

3. Members should encourage their cost engineering and cost management employees to attend and present papers at professional and technical society meetings.

4. Members shall uphold the principle of mutually satisfying relationships between employers and employees with respect to terms of employment including professional grade descriptions, salary ranges, and fringe benefits.

—End of the AACE Canon of Ethics

b. People and Organizations in Enterprises

1. **Leadership:** - Today's leaders must work to promote a team culture and establish partnerships with customers and suppliers. This is done through communication and information sharing among all stakeholders. Leaders now are considered team players. The leader does not work to control team members, but instead works to obtain commitment from them to support goals and objectives by fostering open communication, increased productivity through group efforts, and participatory decision making [S&K 6th Ed., Chap 20].

1. Leadership Roles:

- Leadership is not about imposing control, but about obtaining commitment from people to support enterprise goals and objectives. It's about positively influencing people's behavior toward self-control and enhanced individual and group performance. To obtain commitment from people around objectives, a leader must first understand those enterprise objectives, develop a personal vision of their purpose, and communicate the vision and get other stakeholders to see that they

have a shared purpose. For this, a leader must develop an environment of mutual trust [TCM Framework, 11.2.1].

a. **Managing** – The manager role ensures the project is completed on time, within budget, and at acceptable levels of performance, It involves creating the administrative procedures and structure to monitor completion of the work. The manager role, viewed from the perspective of people challenges, involves creating an administrative system with enough structure and discipline to complete the project without the structure stretching into the realm of excessive bureaucracy. It is important to balance the need for structure and the need for autonomy and flexibility [S&K 6th Ed., Chap 20].

b. **Facilitating** – is one of the more subtle, yet profound roles for the project manager. Facilitation are those behaviors and attitudes that help others get their work done and is often achieved through the art of influencing others. It involves communication abilities, conflict resolution, the ability to actively procure necessary supplies and resources for the team as a whole, and the ability to motivate both individual team members and the team as a unit. The goal is to provide team members with choices, options, and a conducive setting and then trust that the team members will create the desired outcome [S&K 6th Ed., Chap 20].

Facilitation is needed when roadblocks such as conflicts between teams, resource shortages, or other obstacles call for the leader's influence to clear the way or help the team members find paths to do their jobs [TCM Framework, 11.2.2]

c. **Mentoring** – The role of mentor or coach is important when an individual's skills, knowledge, or behavior need development or improvement and some guidance, assistance, feedback, or role modeling might help that individual and, by extension, also help the team [TCM Framework, 11.2.2].

This assistance takes the form of guidance and encouragement, which may or may not be directly tied to an actual project issue being faced by the individual but instead may be directed at assisting the individual in attaining a broader view of future career directions or advancement [S&K 6th Ed., Chap 20].

d. **Participative Management** – otherwise known as employee involvement or participative decision making, encourages the involvement of stakeholders at all levels of an organization in the analysis of problems, development of strategies, and implementation of solutions. By creating a sense of ownership in the company, participative management instills a sense of pride and motivates employees to increase productivity in order to achieve their goals. Employees who participate in the decisions of the company feel like they are a part of the team with a common goal, and find their sense of self-esteem and creative fulfillment heightened. Managers must be willing to relinquish some control to their workers; managers must feel secure in their position in order for participation to be successful. Employees must also be willing to participate and share their ideas. Participative management does not work with employees who are passive or simply do not care. Managers should remember that participative management is not always the appropriate way to handle a given situation. Employees often respect a manager that uses his or her authority and makes decisions when it is necessary [Encyclopedia of Management, Amy McMillan; Revised by Debbie D. DuFrene].

2. **Motivation/Incentives (Behavioral Science):**

Motivation – is defined as “That process, action, or intervention that serves as an incentive for a project team member to take the necessary action to complete a task within the appropriate confines and scope of performance, time and cost” [S&K 6th Ed., Chap 20].

Traditionally, theories of motivation have characterized the subject from the perspective of evolution, biology, drives, needs, and social influences. Each of these perspectives is in agreement that individuals display a wide range of motives [S&K 6th Ed., Chap 20].

- **Biological Perspective** - is considered an evolutionary approach. It asserts that actions or behaviors that contribute favorably to the preservation and expansion of the species will produce motivation [S&K 6th Ed., Chap 20].
- **Drive Theories** – state that certain behaviors are the result of individuals meeting the requirements of specific drives. Drives are considered complex combinations of internal states of tension that cause the individual to take action to reduce the level of tension. The goal of reducing tension is to achieve an internal state of equilibrium or balance or “homeostasis” [S&K 6th Ed., Chap 20].
- **Incentive Theories** – state that individual behavior is pulled in certain directions based on the external conditions in the specific settings. These approaches can work in settings when the manager and team members have the ability and the resources to identify a desired behavior that can be awarded by providing the identified incentive. The incentives must be valued by the group and may need to come directly from the group members. The incentives also need to be appropriate to the culture of the organization [S&K 6th Ed., Chap 20].
- **Theory of Needs** – is another approach to motivation primarily based on work done by David McClelland, who developed the concept that people who value the need for achievement are often those people who are the leaders in the areas of creativity and economic growth. This approach is based on the premises that, as humans, challenging environments provide us with an opportunity to achieve excellence, or to compete against others successfully will provide motivation. The need to achieve and compete within one’s own professional discipline can self-motivate many individuals [S&K 6th Ed., Chap 20].
- **Fear of Failure** – can describe another motivational basis to act and succeed. This approach can be a strong motivator in situations when the consequences for failure are especially distasteful or catastrophic. However, it should be employed only in unusual circumstances, such as if a project is headed for crisis, and immediate action is required [S&K 6th Ed., Chap 20].
- **Hierarchical Theory** – of motivation was set forth by Abraham Maslow. It adopts the premise that the basic physical needs and more subtle social or psychological needs will motivate people. Maslow states that people are motivated by the desire to satisfy these various needs according to a hierarchy, with the most basic needs placed at the bottom of a “needs pyramid.” When one need is satisfied, the individual will then move upward to the next need [S&K 6th Ed., Chap 20].
- **Career Stages** – is a different approach presented by Schein through a model that describes major stages in a person’s career. An understanding of an individual’s current career stage by the leader can be used in developing tangible approaches to individual motivation.

The drivers (i.e., motivators or demotivators) may come from either intrinsic or extrinsic sources. Sources of intrinsic motivation rise from within people, such as a personal desire to

learn or to help others. Extrinsic sources originate from outside the person, such as rewards or improved working conditions. To have an impact, extrinsic sources must either counter or complement intrinsic sources. For example, if a person has no desire to learn, an offer of reimbursement for education costs is unlikely to have an effect on that person's actions. If, however, that person has a desire for money or esteem, an opportunity for higher pay or a better title with an increased level of education may have an effect. A leader must understand a person's intrinsic motivation in order to find extrinsic motivators or incentives that will improve behavior and performance without violating anyone's ethics [TCM Framework, 11.2.1].

Hint: Given a list, be able to describe the basic themes of two or more generally accepted behavioral science theories:

- **McGregor- Theory X and Y** – Douglas McGregor was an early proponent of management as a profession. McGregor stated that management demands a scientific base of research and application to make it a successful profession. He developed two theoretical constructs of the nature of man in relation to his work, known as Theory X and Theory Y.
 - Theory X
 - ✓ The average person has an inherent dislike of work and will avoid it if possible.
 - ✓ The average person must be coerced, controlled, directed, or threatened with punishment to put forth adequate effort toward achievement of organizational objectives.
 - ✓ The average person prefers to be directed, wishes to avoid responsibility, has relatively little ambition, and wants security.
 - ✓ Control should be externally imposed
 - Theory Y
 - ✓ People are self-motivated and will exercise self-direction and self-control toward achieving objectives to which they are committed.
 - ✓ Average people learn to not only accept but also seek responsibility.
 - ✓ People are capable of a high degree of imagination, ingenuity, and creativity in solving organizational problems.
 - ✓ The average person's intellectual potential is only partially used.

Central to a discussion of McGregor's two theories is the matter of control. Under Theory X, control is externally imposed, while Theory Y emphasizes self-control or an internal control. Theory Y implies that within a climate of trust and respect, the employee is capable of putting forth willing effort and controlling work habits [S&K 6th Ed., Chap 20].

- **Herzberg-Motivation-Hygiene** – Frederick Herzberg studied the relationship between the role of work and working conditions. He developed a motivational-hygiene theory based on the concepts of satisfiers and dissatisfiers. He found that real motivation resulted from the worker's involvement in accomplishing an interesting task, not from the working conditions or environmental factors that are peripheral to the job. The hygiene factors, though, must be adequately provided if a person is to rise above them and be able to involve oneself in meaningful tasks. Herzberg's emphasis on job enrichment stated that increasing the challenging content of the job would cause

the employee to grow both in skill and in a feeling of accomplishment [S&K 6th Ed., Chap 20].

- **Argyris-Effects of Organization on Individuals** – Chris Argyris advanced some of McGregor’s theories and said that the organization may be the source and cause of human problems. He believed that individual’s needs and organizational needs were not met effectively in most organizations, as he described the dichotomy between these two sets of needs. Part of the problem, Argyris noted, was because of the bureaucratic nature of organizations and their hierarchical structures; he was an early proponent of the concept of ad hoc work groups, or project teams, that cross-cut organizational lines. Argyris believed that the organization must change to conform to human needs, and that the organization should offer meaningful challenges and opportunities for responsibilities. A climate of open communication and trust is needed in all interpersonal relationships. Argyris advocated the development of interpersonal competence and authenticity in relationships as the first step in dealing with any personal differences that may block information flow and understanding of objectives at the individual, unit, and organizational levels [S&K 6th Ed., Chap 20].

- **Likert-Four Model Systems** – well-known for the development of an attitude measurement approach known as the Likert-type scale, Rensis Likert also developed the concept of the linking pin, a person who belongs to two groups in the organization. The linking pin shows that the entire organization is viewed as a set of overlapping and interacting groups. Likert advocated open communication within groups, development of mutual trust, consensus decision-making, group goal setting, definition of roles, and shared responsibility. Likert further developed four basic styles of leadership related to a wide range of organizational variables:

- ✓ Exploitive-authoritative
- ✓ Benevolent-authoritative
- ✓ Consultative, and
- ✓ Participative group

He believed that participative group, was ideal for a human-concerned organization [S&K 6th Ed., Chap 20].

- **Mouton-Managerial Grid** – Dr. Robert Blake and Dr. Jane Mouton developed a concept called the managerial grid. They believed there was an unnecessary dichotomy in the minds of most managers between concern for people problems and concern for production problems. These concerns are complementary. They said that each manager has a discernible style of management based on the degree of concern for production and people. At one end is the manager who is only concerned with production; at the other end is the manager who coddles people at the cost of lost production. There are 81 possible positions on their managerial grid. Ideally, on the grid, a manager should be a 9.9. This manager stresses team management. Concerns for people and production are independent. The manager’s job is one of a coach, an advisor, or a consultant [S&K 6th Ed., Chap 20].

3. **Performance/Productivity Management:**

- a. **Productivity** – A measure of output relative to input. Productivity (or efficiency) is improved by increasing output for a given input, or decreasing input for a given output. If the input is specifically work hours, the term commonly used is labor productivity [RP10S-90].

- b. **Labor Productivity** – A measure of production output relative to labor input. In economics, industrial engineering, and earned value management, quantity/work hour measures are common (higher values reflect higher productivity or efficiency). In cost estimating, inverse measures such as work hours/quantity or unit hours are common (where lower values reflect higher productivity or efficiency). Regardless of the measure used, labor productivity (or efficiency) is improved by increasing production for a given work hour or decreasing work hours for a given production [RP10S-90].
- c. **Production Rate** – The amount of work, which may be accomplished in a given unit of time [RP10S-90].

In general terms, labor productivity is defined as the ratio of the value that labor produces to the value invested in labor. In an absolute sense, it is a measure of the extent to which labor resources are minimized and wasted effort is eliminated from a work process (i.e., work process efficiency). In earned value assessment productivity is a ratio (i.e., a factor) that compares the labor effort expended to that which was planned (sometimes called the “spent-earned ratio”). In earned value terms, productivity is calculated as follows:

Labor Productivity Factor = Expended Hours / Earned Hours, where the earned hours = percent physical progress x control budget hours [TCM Framework, 10.1].

- Crew balance of skills
 - Worker skill level samples
 - High +2% to 5%
 - Average +6% to 10%
 - Poor +11% to 20%

[Richardson Estimating System; S&K 6th Ed., Chap 4]

- immediate supervision competence
- overall supervision competence
- worker and supervision attitudes
- work force sociological, cultural and demographic characteristics
- absenteeism and turnover
- overtime
- Sample adjustments to productivity rates:
 - Work weeks in excess of 40 hours
 - 40 to 48 hours +5% to 10%
 - 49 to 50 hours +11% to 15%
 - 51 to 54 hours +16% to 20%
 - 55 to 59 hours +21% to 25%
 - 60 to 65 hours +26% to 30%
 - 66 to 72 hours +31% to 40%

[Richardson Estimating System; S&K 6th Ed., Chap 4]

- level of technology used
- Learning Curve

- A graphic representation of the process in production effectiveness as time passes. Learning curves are useful planning tools, particularly in the project oriented industries where new products and workers are phased in rather frequently. The basis for the learning curve calculation is the fact that workers will be able to perform work more quickly after they get used to performing it [RP10S-90].
 - One of the most important items affecting learning curve is the productivity improvement that results from a crew performing repetitive type operations. In a manufacturing environment or a construction project where similar kinds of work are done, the more the crew does the work, the faster and more efficient they become as they become familiar with working together, using the tools, possibly fabricating special tooling to make the work easier and faster, etc. This needs to be encouraged and factored into any budget or estimate made [S&K 6th Ed., Chap 4].
 - Work area environment samples
 - Jobsite Conditions
 - Good +3% to 5%
 - Average +6% to 8%
 - Poor +9% to 15%
- [Richardson Estimating System; S&K 6th Ed., Chap 4].
- Weather
 - Temperature below 40 degrees or above 85 degrees add one percent per degree of variance for adjustment to productivity rate [Richardson Estimating System; S&K 6th Ed., Chap 4].
 - geographic location
 - proximity to other work and contractors
 - job layout
 - work rules
 - safety practices
 - quality control practices (including quality circles)
 - materials and tools availability
 - Wages, salaries and benefits.

2. Organization Structure

1. Organizational Design:

- Traditionally, the design of an organization structure must consider the following principles:
 - a) **Division of Labor** – Consider departmentalization or specialization
 - b) **Unity of Command** – Consider lines or chains of command
 - c) **Unity of Directions** – Consider authority and responsibility

- d) **Span of Control** – Consider levels of control and degree of centralization [TCM Framework 11.2.3].

2. **Basic Structures:**

- Traditionally, there are three structural design frameworks used, for which the preceding principles are considered:
 - a) **Functional** – Focused on division of labor or specialization (i.e., cost engineering) Functional designs encourage expertise development and avoid duplication of resources, but tend to be “siloesd” or more focused on the needs of the specialty than the integration of specialties needed to serve processes, products, or customers.
 - b) **Divisional** – Focused on unity of command and direction concerning product lines and/or regions. Typically, each division is organized functionally. Divisional design improve the focus on product and customers and decision making concerning them, but tend to use resources inefficiently because each division uses functional organization, which may foster detrimental rivalries.
 - c) **Matrix** – Focused on tasks – Typically, task managers draw resources from functional and divisional organizations as needed. Matrix designs use resources efficiently and have a focus on the task (i.e., process, product, project, or customer), but they complicate decision making and allocation of resources because lines of authority are less clear (e.g., a person may have two supervisors: functional and project).

Typically, each design will have lateral or “dotted line” relationships, liaisons, and temporary attributes to meet special needs [TCM Framework, 11.2.3].

3. **Teams:**

- a. The matrix design complicates decision making because team, functional, and divisional managers may have conflicting authority over resources. Team members that report to multiple supervisors may become confused as to whom they should listen. This situation places a premium on leadership and planning [TCM Framework, 11.2.3].
- b. Each TCM (Total Cost Management) map includes a planning step in which roles, authority, and responsibility are established. Also, the resource planning and procurement planning processes must consider the owner and contractor organization structures and how they will interact. These processes must also consider whether the owner or contractor has sufficient qualified resources for specific roles and activities [TCM Framework, 11.2.3].
- c. Few endeavors of an enterprise are undertaken by individuals acting alone. Significant and challenging activities can only be accomplished through integrated efforts of several individuals. However, highly performing, successful teams do not just happen; they are built by leaders who can obtain the team member commitment, despite sometimes differing personal objectives, to support enterprise goals and objectives [TCM Framework, 11.2.2].

- d. Team member's differences are both challenges and opportunities. Differences in the way team members think and act can be leveraged so that a team takes a balanced approach to problems. Differences in team members' cultural backgrounds can be taken advantage of in the same way. However, the attributes that add richness to a team may also add more complications for the leader to work through. Significant differences and conflicts should always be addressed, not ignored [TCM Framework, 11.2.2].

4. **Typical Organizations in TCM:**

- ✓ While the TCM project control process almost always employs teams organized in a matrix structure, it is more common to find a divisional structure used for the strategic asset management process because the division usually "owns" and operates the asset (i.e., operational management) and has a less temporary focus than a project team. A division may have its own established capital management or strategic planning department, function, or team that handles much of the asset management process. However, when separate divisions within the enterprise are given authority to decide on major investments for their part of the asset portfolio, there is a risk that the decisions will be biased, often unintentionally, by their parochial needs and desires and by competitive instincts (i.e., "pet projects") [TCM Framework, 11.2.3].

c. **Information Management**

1. **Data, Information, and Knowledge:**

- ✓ Data are the raw material of information management. Data include text, numbers, images, and so on that are generally not organized in a way to make them useful.
- ✓ Information is data that has been processed and presented in a way that makes it useful; that is, it enables knowledge to be obtained.
- ✓ Knowledge is learning from information about the past, present, and possible future. It confirms that past activities have or have not resulted in desired outcomes. It enables people to start altering their behavior to optimize future results (i.e., continuous improvement), or to speculate in the possible ways inputs may be related to outputs for the processes they are interested in [TCM Framework, 11.3.1].

2. **Databases and Database Management.**

1. **History:**

- ✓ **Historic Records** – Documentation from past projects that can be used to predict trends, analyze feasibility and highlight problem areas/pitfalls on future similar projects [RP 10S-90].
- ✓ **Historical Database** – Records accumulating past project experience stored as data for use in planning, estimating, forecasting and predicting future events. Often includes data that has been processed so as to facilitate planning and other purposes such as validation and benchmarking (e.g., metrics, etc.) [RP 10S-90].

2. **Reference Data:**

- ✓ The reference data should be consistent, reliable, and competitive with a well-defined basis (e.g., assumptions, conditions, etc.) such that any asset planning effort can determine how its requirements and basis conditions differ from the reference and adjust accordingly. Reference data are typically normalized to a standard basis (i.e., in terms of time, location, currency, conditions, etc.) [TCM Framework, 6.3.2].

3. **Lessons Learned:**

- ✓ A project team's learning, usually defined during close out. Should be limited to capturing/identifying work process improvements. A finding that established policies or procedures were not followed is not a valid lessons learned [RP 10S-90].
- ✓ Lessons learned is qualitative information that describes what was learned during the performance of a process, method, or tool. Lessons learned are typically elicited through the use of subjective surveys, narrative descriptions, interviews, or formal lessons learned workshops. Lessons learned are captured in a database to support ongoing development or improvement of processes, methods, and tools [TCM Framework 6.1.2].

4. **Metric:**

- ✓ Benchmarking and metrics are a form of reference data, but the purpose is primarily to support the validation of asset planning [TCM Framework, 6.3.2].

5. **Validation:**

- ✓ Testing to confirm that a product or service satisfies user or stakeholder needs. Note difference from verification [RP 10S-90].

6. **Basis:**

- ✓ The quality of a reference database is judged by how reliable a planning "base" it is in terms of competitiveness and consistency, with consistency meaning that the basis is known and is consistent between similar items and does not change over time unless the change has been justified by analysis [TCM Framework, 6.3.2].

7. **Normalization:**

- ✓ In database management, a process used to modify data so that it conforms to a standard or norm (e.g., conform to a common basis in time, currency, location, etc) [RP 10S-90].

3. **Information Technology (IT) and Systems:**

- ✓ Information systems are the mechanisms or tools by which knowledge is delivered to the enterprise and those it interacts with. They include hardware and software information technology (IT), which may include not only computers, but also telecommunications hardware, the Internet, or even a cork bulletin board. Information systems also include specific methodologies to build, select, and deliver IT solutions [TCM Framework, 11.3.1]

1. **Enterprise Resource Planning/Management (ERP/ERM):**

- ✓ Program / project resource planning of activities, supported by multi-module application software and processes to help an enterprise manage key parts of its business which may include product planning, maintaining inventories, supply chain processes, providing customer services, human resources planning, etc. It may include other system involving any kind of resource consumption that can benefit from integration of information across many functional areas [RP 10S-90].

d. **Quality Management:**

1. **Quality:** Conformance to established requirements (not a degree of goodness) [RP 10S-90].

2. Requirements:

- ✓ An established requisite characteristic of a product, process, or service. A characteristic is a physical or chemical property, a dimension, a temperature, a pressure or any other specification used to define the nature of a product, process or service.
- ✓ A negotiated set of measurable customer wants and needs [RP 10S-90].

3. Quality Planning:

- ✓ Identifies the quality features to be provided and plans for delivering them without deficiencies. Again, quality planning is not a separate process or function, but an integrated way of planning directed toward satisfying customer needs [TCM Framework, 11.4.3].
- ✓ Translating customer needs into characteristics or products and service lines (e.g., quality function deployment analysis) [S&K6th Ed., Chap 21].

4. Quality Management: Concerns the optimization of the quality activities involved in producing a quality product, process or service. As such, it includes appraisal, training, and prevention activities [RP 10S-90].

5. Quality Assurance: All those planned or systematic actions necessary to provide adequate confidence that a product, process, or service will conform to established requirements [RP 10S-90].

6. Quality Control:

- ✓ Inspection, test, evaluation or other necessary action to verify that a product, process, or service conforms to established requirements and specifications [RP 10S-90].
- ✓ Measuring quality levels and comparing them against desired levels (i.e., removing sporadic deficiencies) [S&K 6th Ed., Chap 21].
- ✓ Maintains the results achieved through Quality Planning and Quality Improvement [TCM Framework, 11.4.3].

7. Continuous Improvement: TCM is not about repeating history, but improving on it by performance-focused planning. The PDCA model is specifically a continuous improvement model [TCM Framework, 11.4.1].

8. Plan-Do-Check-Assess (PDCA):

- ✓ Universal improvement methodology, advanced by W. Edwards Deming and based on the work of Walter Shewhart, designed to continually improve processes by which an organization produces a product or delivers a service [RP 10S-90].
- ✓ The foundation for the Total Cost Management (TCM) process is synonymous with the Deming Cycle [RP 10S-90].
- ✓ PDCA is a time honored quality management approach sometimes called the Deming or Shewhart cycle [TCM Framework, 11.4.1].
- ✓ An interactive approach to achieving preventive and corrective solutions. Some now have reduced PDCA to a more simple “Do-and-Reflect.” Regardless of the quality techniques applied, financial measures will be increasingly relevant as organizations move from decisions based on instinct and intuition toward fact-based decisions [S&K 6th Ed., Chap 21].

9. **Quality Measurement:** If an organization makes the effort to collect data, validate the information, and report it, it might as well use the information. In fact, to state the obvious, the amount of use of and utility in the information will be proportional to the length of life of the COQ measurement system. In short, the uses of a COQ measurement system can range from favorably influencing employee attitudes toward quality management by quantifying the financial impact of changes to assisting in prioritizing improvement opportunities.
10. **Quality Policy:** Is an imposed requirement, meaning the enterpriser's quality management strategy and approach is already established; TCM is a process to deploy that policy. In TCM, it is assumed that quality policy will reflect the ISO principles [TCM Framework, 11.4.2].
11. **Quality Standards:** Possibly the most widely recognized authorities for establishing and maintaining standards are the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI) [TCM Framework, 11.4.2].
1. **ISO 9000** is focused on an enterprise having, maintaining, and following a documented quality process and procedures. Enterprises apply and seek certification in the standard to assure their customers that they have a quality management system in place. [TCM Framework, 11.4.2].
 2. **ISO 10006** is focused specifically on project management.
12. **Quality Focused Practices in TCM**
1. **Benchmarking**
 - ✓ A measurement and analysis process that compares practices, processes, and relevant measures to those of a selected basis of comparison (i.e., the benchmark) with the goal of improving performance. The comparison basis includes internal or external competitive or best practices, processes or measures. Examples of measures include estimated costs, actual costs, schedule durations, resource quantities, etc. [RP 10S-90].
 - ✓ The method can support both continuous and breakthrough improvements depending on whether "best" practice benchmarks are viewed as goals to be achieved or exceeded [TCM Framework, 11.4.4].
 - ✓ The benchmarking process identifies not only "benchmarks," but also "enablers," which are practices that facilitate best, or at least improved, performance [TCM Framework, 6.1.2].
 2. **Cost of Quality**
 - ✓ Consists of the sum of those costs associated with (a) Cost of quality conformance; (b) Cost of quality nonconformance; and (c) Cost of lost business advantage [RP 10S-90].
 - ✓ Cost incurred or expanded to ensure quality, including those associated with the cost of conformance and nonconformance [RP 10S-90].
 - ✓ Cost of quality refers to the cost of error-free, conforming, and not conforming (i.e., at variance) with these requirements. Costs of quality are generally analyzed in the following five categories: error-free, prevention-related, appraisal-related, internal failure, and external failure. Prevention and appraisal

costs, such as employee training or product testing, are essentially designed into the asset or process during asset planning, so performance assessment tends to focus on the “resultant” cost or variance during the asset’s use [TCM Framework 6.1.1].

3. Value Analysis/Engineering

- ✓ The objective of the value analysis (VA) study is to improve the value for the intended project objectives. This VA practice covers a procedure for defining and satisfying the requirements of the user/owner’s project. A multidisciplinary team uses the procedure to convert design criteria and specifications into descriptions of project functions and then relates these functions to revenues and costs [S&K 6th Ed., Chap 22].
- ✓ A practice function targeted at the design itself, which has as its objective the development of design of a facility or item that will yield least life-cycle costs or provide greatest value while satisfying all performance and other criteria established for it [RP 10S-90].
- ✓ **Value Analysis (VA) and value Engineering (VE)**, when applied as processes, are, “the” systematic application of recognized techniques which identify the function of the product or service, establish the worth of those functions, and provide the necessary functions to meet the required performance at the lowest overall cost. Typically, lowest overall cost refers to the lowest life-cycle cost. While VE is focused on the development of new assets, and VA on existing assets or projects, their representation in a basic process map is the same [TCM Framework 7.5.1].
- ✓ This is the application of value engineering methodology to the review of a partially complete or complete design, existing facility, or existing service to determine if it could be improved to better meet cost or other objectives [S&K 6th Ed., Chap 22].

4. Change Management

- ✓ The formal process through which changes to the project plan are identified, assessed, reviewed, approved and introduced [RP 10S-90].

e. Value Management:

1. **Value** – A common answer might be that the amount of value received is determined by comparing what something is worth to an individual or business as compared to what was paid for it or the effort involved in its creation. There is no single type of value; instead there are these types:

- ✓ **Cost Value** – This is the amount of money (or monetary equivalents) that must be spent to produce or purchase an item [S&K 6th Ed., Chap 22].
- ✓ **Exchange Value** – This is the value of an item on the open market should one try to sell or trade it. The exchange value of a new car drops in comparison to its cost value as soon as the new owner takes the car from the showroom [S&K 6th Ed., Chap 22].

- ✓ **Use Value** – This is the value of an item to the user because of the functions or services it provides. A well-maintained, basic old car may have little exchange value, but just as much use value to the owner as a newer, fancier car. The use value would equal the cost value of equally reliable replacement transportation [S&K 6th Ed., Chap 22].
 - ✓ **Esteem Value** – This is a value “in the eyes of the beholder” or a consequential that has evolved. A gold bracelet has a definite cost value, its exchange value is usually less than its cost, it has no use value, but it has an esteem value to an individual who loves jewelry. A favorable image is of extreme esteem value to a company but could be converted into monetary terms only if someone sought to buy the company name [S&K 6th Ed., Chap 22].
 - ✓ **Satisfaction Value** – This is essentially a combination of the above types of value [S&K 6th Ed., Chap 22].
2. **Value Management**
 - ✓ Is an umbrella term encompassing those practices designed to maximize the value of a project, item, or service through the examination of relevant considerations and the involvement of a decision using a value system established by the client [S&K 6th Ed., Chap 22].
 3. **Value Engineering**
 - ✓ A practice function targeted at the design itself, which has as its objective the development of design of a facility or item that will yield least life-cycle costs or provide greatest value while satisfying all performance and other criteria established for it [RP10S-90].
 4. **Value Improving Practices (VIP)** Some criteria to be considered a VIP may include:
 - ✓ A formal, planned process with assigned responsibilities.
 - ✓ A facilitated effort led by an independent practice expert.
 - ✓ Involves all key stakeholders.
 - ✓ Documents, communicates, and follows up on the results [TCM Framework, 11.5.1].
 5. **Manufacturability Analysis**
 - ✓ Is used during asset planning to optimize product and production system design in consideration of the effective performance of manufacturing and related activities. Alternate materials, manufacturing technologies, and standardization are key considerations (e.g., use common parts for different products) [TCM Framework, 11.5.1].
 6. **Constructability Analysis**
 - ✓ Is used during construction project planning and it involves methods to optimize the design in construction of the effective performance of construction activities. Alternate materials, unique construction sequencing (i.e., activity logic), and construction technologies are key considerations [TCM Framework, 11.5.1].
 - ✓ Is a form of both value engineering and value analysis that focuses on the construction phase only [S&K 6th Ed., Chap 5].

7. Reliability, Availability and Maintainability (RAM) Analysis

- ✓ Is used primarily during asset planning. It involves using quantitative methods to optimize the performance or operation (i.e., operability) of process systems and their components. RAM methods generally employ predictive modeling and simulation that consider future asset performance [TCM Framework, 11.5.1].

f. Environment, Health, Safety, and Security (EHS):

1. Quality Management.

Phil Crosby, one of the most recognized authorities on quality management, established four “absolutes” of quality management:

- Quality is defined as conformance to requirements, not “goodness.”
- The system for causing quality is prevention, not appraisal.
- The performance standard must be zero defects, not “close enough.”
- The measurement of quality is the Price of Nonconformance, not indices.

In other words, Crosby is saying that quality comes from planning and design, and the best measure of quality is cost. From that perspective, cost engineering, applied in the TCM process, is arguably a more central function to quality management than quality assurance and control. Crosby goes on further to say that quality is too important to be left to the quality control department, meaning that management must create a system that results in quality; a system in which TCM and cost engineers should play a key role [TCM Framework ,11.4.1]

2. Non-Conformance/Prevention.

Building EHS requirements into a quality management system like TCM has a profound impact on how corporations view EHS costs and account for them, In the past (and too often at present), management focus was on minimizing the cost of compliance and control (i.e., cost of non-conformance) inspection, fines, penalties, treatment facilities, site remediation, and so on. However, more proactive enterprises are talking TCM’s quality management approach and focusing on cost prevention through better design while considering the life cycle costs of their assets. TCM plans, measures, and assesses the full economic costs (including hidden opportunity costs) of the enterprise’s asset and project portfolio including prevention, appraisal, and failure costs in regard to EHS requirements [TCM Framework, 11.6.1].

3. EHS Standards/Compliance.

1. ISO 14000:

For environmental management, arguably the most significant voluntary standard is the International Organization of Standardization (ISO) ISO 14000. As with ISO 9000 (see Section 11.4 TCM Framework), the ISO 14000 series of standards pertain to the management systems that an organization employs to manage environmental matters, not to the environmental performance of the organization. The standard provides a framework for setting environmental requirements and for implementing them and assessing performance against them. ISO also publishes numerous safety standards that are usually for very specific applications [TCM Framework, 11.6.2].

2. Sustainable Development

Sustainable development is another life cycle issue to consider. As economic developments proceeds throughout the world, development actions must be carried out in a fashion that does not use resources in a manner or degree that compromises the ability of future generations to sustain such development. In other words, as a matter of strategy for an enterprise, planning must not only

consider the life cycle cost of the asset, but the life cycle of the environment and its asset value as natural capital [TCM Framework, 11.6.2].

4. Cost Engineering Terminology (Recommended Practice No. 10S-90)

LIFE CYCLE – The stages, or phases that occur during the lifetime of an object or endeavor. A life cycle presumes a beginning and an end with each end implying a new beginning. In life cycle cost or investment analysis, the life cycle is the length of time over which an investment is analyzed (i.e., study period) [RP 10S-90].

QUALITY CONFORMANCE – Quality management activities associated with appraisal, training, and prevention adapted to achieve zero deviations from the established requirements [RP 10S-90].

QUALITY NONCONFORMANCE – A deviation that occurs with a severity sufficient to consider rejection of the product, process, or service. In some situations the product, process, or service may be accepted as is; in other situations, it will require corrective action. It also may involve the provision of deliverables that are more than required [RP 10S-90].

Note: This Primer contains references to AACE International’s **Skills and Knowledge of Cost Engineering, 4th Edition** (S&K 4th Ed). As of 2018, the current and only available book in print and digital is S&K 6th Ed.

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