April 15th, 16th and 23rd 2021 – Online Training

Certified Cost Professional (CCP) Workshop

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Philip D. Larson, CCP, CEP, PMP, PSP, FAACE, FRICS
Reza Dehghan, Ph.D., PMP, CCP

3Targets Consultants Ltd.

Certified Cost Professional (CCP) Workshop

Objective

- The focus of this workshop is to prepare attendees for the CCP exam by reviewing subjects covered on the exam and working through various sample questions.
- Individuals who want to obtain a general knowledge about project controls and cost engineering can also benefit from the workshop.

Instructors

Cindy Hands, P.Eng, MCL, CCP

- Maters Degree in leadership
- Professional Engineer and BEng in Civil Engineering
- Past President and long standing member of the Board of Directors for AACE's Chinook-Calgary Section
- Past President AACE Canada (Regional Director Region 1)
- AACE International VP-North America and Chair of Membership Board
- Project Controls Manager- Western Canada- Hatch Ltd.
- 30 years industry experience
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Instructors

Philip D. Larson CCP, CEP, PMP, PSP, FAACE, FRICS

- Program Manager of Cost Engineering – Sound Transit
- 40+ years industry experience
- AACE International President (2005-06)
- Email: p.larson@3targets.com

Instructors

Reza Dehghan, Ph.D., PMP, CCP

- PhD in civil engineering, project management
- MSc in chemical engineering, oil and gas processes
- Past President of AACE's Chinook-Calgary Section
- 25 years work experience as a project engineer and project controls specialist in oil and gas projects
- Email: r.dehghan@3targets.com

The Company

3Targets Consultants Ltd.

- A Canadian private incorporation
- AACE's Approved Education Provider (AEP)
- PMI's Registered Education Provider (REP)
- Project management and project controls training
- Run and operated by university academics and industry practitioners

Introduction

Ground Rules

- Participate in the discussions, share your experience
- Feel free to ask questions related to the workshop subjects
- Participate in solving sample questions
- Unless you want to ask a question or make a comment, keep your microphone off to prevent feedback during the training
- In order to have more engaged discussions, we encourage the participants to leave their cameras on
- To comply with education credit requirements, presence during the three days is required

Course Outline

- **Day 1**
  - Section 1: Cost
  - Section 2A: Basic Cost Economics
  - Section 2B: Cost Estimating
- **Day 2**
  - Section 3A: Planning
  - Section 3B: Scheduling
  - Section 4: Progress and Cost Control
  - Section 5: Project Management
- **Day 3**
  - Section 6: Economic Analysis
  - Section 7: Statistics, Probability, and Risk
  - Section 8: Technical Paper Writing

Days Schedule

- 8:00 – 10:00 Session 1
- 10:00 – 10:15 Break 
- 10:15 – 12:00 Session 2
- 12: 00 – 12:30 Lunch Break 
- 12:30 – 14:15 Session 3
- 14:15 – 14:30 Break 
- 14:30 – 16:15 Session 4
- 16:15 – 16:30 Q&A

Section 1: Cost

Cost Outline

Introduction

- Definition of Cost and Cost Engineering
- Fundamental Attributes of Cost

Basic Concepts

- Cost Elements
- Pricing
- Materials
- labor
- Engineering
  - General
  - Process Product Manufacturing
  - Discrete Product Manufacturing
- Equipment, Parts and Tools
- Economic Costs
- Activity Based Cost Management

Cost

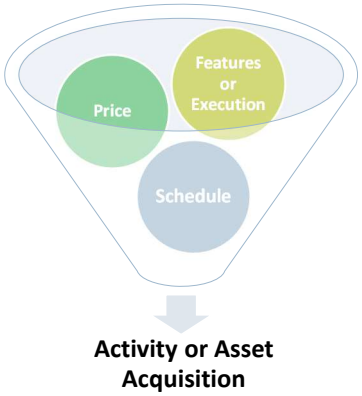
Introduction

- Cost
  - the basic “yard stick” by which activities and assets are measured and compared
- Cost Engineering
  - the application of scientific principles and techniques

Cost

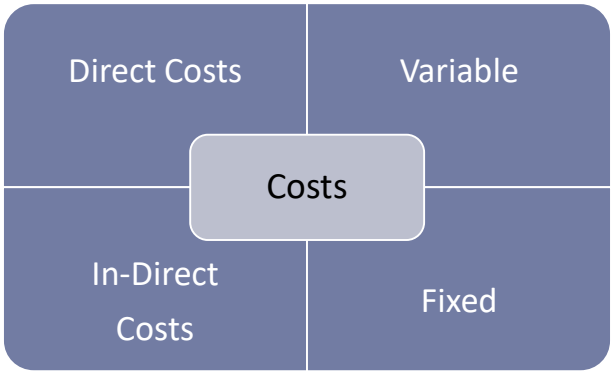
Fundamental Attributes

- Fundamental attributes when performing an activity:
  - Price (cost)
  - Features/Execution
    - how an activity will be performed)
  - Schedule (and/or availability)



Cost

Common Cost Elements



Cost

Common Cost Elements

- **Direct Costs**
  - Construction
    - cost of installed equipment
    - materials
    - labor ‘directly’ involved in the physical construction of the permanent facility
- **Manufacturing**
  - the portion of operating costs that is generally assignable to a specific product or process area

Cost

Common Cost Elements

- **In-Direct Costs**
  - Construction
    - costs which are not a final part of the installation, but are required to complete the installation
    - field administration, direct supervision, tools, etc.
- **Manufacturing**
  - costs not directly assignable to the end product/process
  - overheads, general labor, transport and distribution
  - insurance, property taxes, maintenance, depreciation, etc.
  - in government contracts, indirect costs are often calculated as a fixed percent of direct payroll cost

Cost

Common Cost Elements

- **Fixed Costs**
  - Those costs independent of short-term variations in output
  - Includes:
    - maintenance
    - a portion of plant overhead
    - administrative
    - selling and research expenses
    - property taxes and insurance
    - royalties (can also be variable)
    - depreciation

Cost

Common Cost Elements

- **Variable Costs**
  - Those costs that are a function of production
    - raw materials
    - by-product credits
    - Royalties (can also be fixed)
    - processing costs - vary with plant output such as utilities, catalysts and chemicals, packaging and labor for batch operations

Cost

Common Cost Elements

- **Semi-variable Costs**
  - Those costs which are partially proportional to production level may include:
    - direct labor, supervision, general expense, and plant overhead

Cost

Code of Accounts (COA)

- A systematic coding structure for organizing and managing assets, cost, resources, and schedule activity information
- Facilitate finding, sorting, compiling, summarizing, and managing information
- Includes definitions of the content of each account
- A WBS (work breakdown structure) can be used within a code of accounts
- Facilitates “sound cost accounting”:
  - consistent, historical reporting of disbursements, costs and expenditures on a project
  - aids cost analysis and budgeting

Cost

Element of Cost Management

- **Cost Estimating**
  - Prediction of costs and quantities (for work not yet started)
- **Cost Trending**
  - Analysis of how costs are tracking
  - Established from historical cost accounting information

Cost

Element of Cost Management

- **Cost Forecasting**
  - Prediction of costs and quantities (using cost data from work in progress)
- **Life-Cycle Costing**
  - Extends the costs beyond the asset cost (capital and or acquisition costs)
  - Includes operating costs and disposal costs (sales of products and services)

Cost

Cost and Pricing

- **Difference between cost, price and pricing?**
  - Cost
    - Amount of money incurred by the supplier to produce the product or service
  - Price
    - Simply the cost at which something is bought or sold (price tag)
  - Pricing
    - The management processes (tools and techniques) required to establish the cost of an endeavor (project or business)

Cost

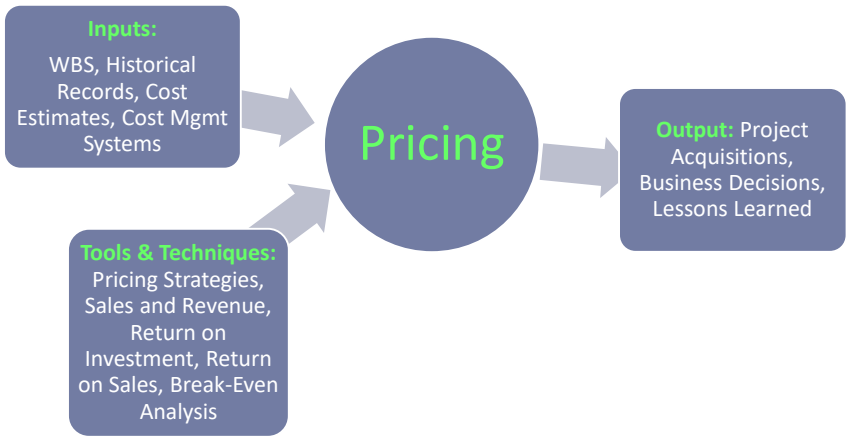
Pricing Strategies

- **Type I Acquisition**
  - Win a project and execute "profitably" and satisfactorily according to contractual agreements

- **Type II Acquisition**
  - Win a project and execute satisfactorily according to contractual agreements
  - Less focus on profits – more focus on new business opportunity (growth in portfolio)

Cost

Pricing Summary



Cost

Business and Economic Ratios

- **Return on Investment (ROI)**
  - Compares expected gains to investment cost (expressed as %)

- **Simple ROI**

$$= \frac{(\text{Gains} - \text{Investment Cost})}{\text{Investment Costs}}$$

- **Complex ROI**

$$= \frac{\text{Avg. yearly profits during earnings life}}{\text{Original Fixed Investment + Working Capital}}$$

Cost

Business and Economic Ratios

- **Return on Average Investment (RAI)**

$$= \frac{\text{Avg. yearly profits during earnings life}}{\text{Avg. Outstanding Investment}}$$

- **Return on Sales (ROS)**
  - compares after tax profit to sales

$$\text{ROS} = \frac{\text{Net Profit}}{\text{Sales}}$$

Cost

Business and Economic Ratios

- **Return on Assets (ROA)**
  - Tells you how effective your business is

$$\text{ROA} = \frac{\text{Earnings before Interest and Taxes (EBIT)}}{\text{Net Operating Assets}}$$

- **Gross Profit Margin Ratio**

$$= \frac{\text{Gross Profit}}{\text{Total Sales}}$$

Cost

Business and Economic Ratios

- **Break-Even Analysis**
  - Involves finding the level of sales necessary to operate a business on a break-even basis equals
  - The point where "income equals total operating costs"
  - Formulas:

$$X = \frac{FC}{(SP - VC)} \quad \text{or} \quad X = \frac{FC}{CM}$$

Where: SP = Selling price ($/unit)
VC = Variable Costs ($/unit)
CM = Contribution Margin = SP – VC
FC = Fixed Cost (lump sum cost)
X = Units (quantity sold or produced)

Note: Break-even Revenue ($) = Break-even Units x Selling Price

Cost Exercise

Questions: Cost Elements & Pricing

- Complete questions 1 through 10.

Cost

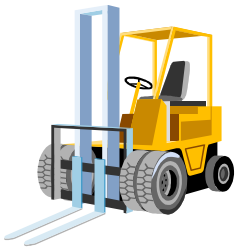
Materials

- **Material Selection**
  - Economics and market conditions often drives the selection of a particular material for use in a final product
  - The best material type must also be balanced with risk, selling economics, safety and the intended use

Cost

Materials

- **Materials Handling Considerations**
  - Travel distance,
  - Work space, terminal and cycle times
  - Manual handling versus automated
  - Shipping, expediting and double-handling
  - Identification, tracking and monitoring

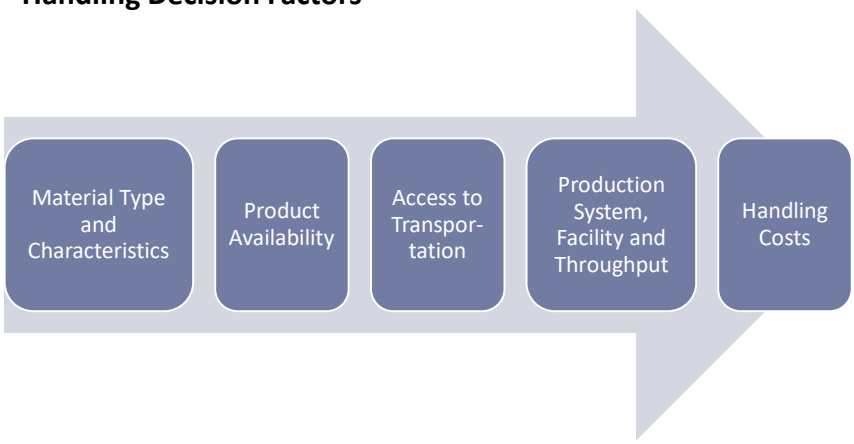


Note: “Poor material handling can result in damage to raw materials or the final product”

Cost

Materials

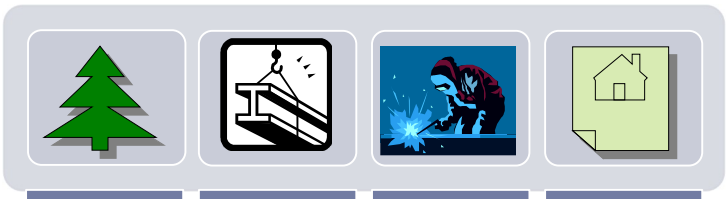
- **Handling Decision Factors**



Cost

Materials

- **Basic Material Categories**



Raw Materials
- trees
- coal
- bitumen

Bulk Materials
- Partially Processed
  - steel
  - pipe
  - cables

Fabricated Materials
- customized bulks
- pipe rack
- pipe spools

Engineered or Designed Materials
- building
- bridge

Cost

Materials

- **Material Quality**
  - Requires predetermined standards and specifications to measure materials acceptance
  - **Vendor Surveillance and Traceability**
    - Surveillance is the periodic inspection by purchasers at the vendors' location(s)
    - ensure conformance with performance standards and specifications
    - Traceability ensures no substitution of the product

Note: "The purchasing and management of materials can be the key to offering competitive prices"

Cost

Materials

- **Formulas**
  - Economic Order Quantity (EOQ):

    $EOQ = \text{Square Root of } (2 \times D \times (P \div S))$

    Where: D = annual demand
    P = purchase order costs
    S = storage / carrying costs
- Re-Order Point

  $RP = (O \times R) + I$

  Where: O = order time,
  R = production rate
  I = minimum inventory level or safety stock.

Cost

Three main types of labor Costs

- **Direct labor**
  - "directly" involved in building the permanent facility
  - trades people
    - carpenters, pipe fitters, etc.
    - working foreman

- **Indirect labor**
    - "not directly" involved (arms-length) from the actual building or manufacturing
    - construction mgmt
    - general foreman
    - cost controllers and schedulers
    - payroll clerks, site procurement, site computer support

Cost

Three main types of labor Costs

- **Overhead labor**
  - HO procurement
  - human resources
  - corporate computer support
  - legal
  - estimating
  - business development

Cost

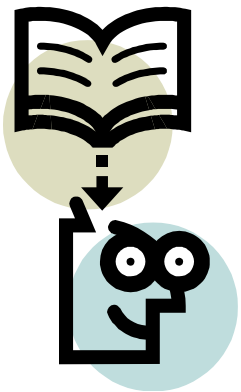
Common labor Calculations

- **Weighted Average Rates / Composite Crew Rates**
  - Averaging of different experience and skill levels
- **Methods for Estimating Indirect and Overhead labor Costs**
  - Total staff hours applied to wage rates to compute indirect labor (bottoms-up estimate)
  - Historical data to compute a percentage adder
- **Work Hours to Complete**
  - Use labor Productivity Adjustment Factors (SPI and CPI)

Cost

Engineering – Research

- **Pure or Basic Research:**
  - involves work 'without' a specific end product or use in mind
  - most often take place at universities or foundations
    - may be financed from government grants or private sector grants
  - Example: examining the strength impact of various concrete additives



Cost

Engineering – Research

- **Applied Research:**
  - is the attempt to develop usable products or new add-on features to existing products
  - more specific that pure research, and is typically carried out by the organization producing the product
  - Note: Patent Duration in the US is 17 years

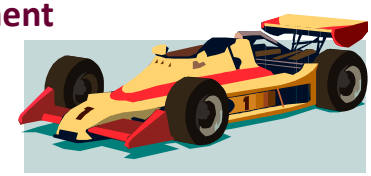
Cost

Engineering - Product Development

- **Standardization in Manufacturing**
  - Is the attempt to base product designs, in whole or in part, on existing product items and tooling
  - **Advantages**
    - Less investment in spare parts
    - Shorter time to market
    - Fewer equipment components resulting in faster repairs
    - Lower costs
  - **Disadvantages**
    - If there is a product flaw, the flaw will be spread over a wide variety of products.

Cost

Engineering - Product Development

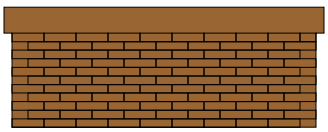


- **Process Selection**
  - Continuous Production
    - Pros:
      - less investment in spare parts
      - shorter time to market
      - fewer equipment components resulting in faster repairs
      - lower overall costs (ex. automotive industry)
    - Cons:
      - if there are product flaws, the flaws will be spread over a wide variety of products

Cost

Engineering - Process Development

- **Process Selection**
  - Discrete Production
    - Pros:
      - uses general-purpose equipment such as forklifts, fabrication shops and machining centers (ex. retaining wall)
    - Cons:
      - Higher overall labor Costs



Cost

Engineering - Process Product Manufacturing

- **Break-Even Analysis**
  - In a manufacturing environment, the break-even point can be calculated for operations of less than full-capacity
  - Formula:

$$\textbf{B (breakeven point)} = \frac{(F + nR)}{S - V - (1 - n)R}$$

Where: F = the fixed expense
V = the variable expense
R = the semi-variable expense
S = sales income
n = decimal fraction of semi-variable costs incurred at 0 production; usually about 0.3

Cost

Engineering - Process Product Manufacturing

- **Shutdown Point Analysis**
  - In a manufacturing environment the shutdown point can also be calculated
  - Formula:

$$\textbf{A (shutdown point)} = \frac{nR}{S - V - (1 - n)R}$$

Where: V = the variable expense
R = the semi-variable expense
S = sales income
n = decimal fraction of semi-variable costs incurred at 0 production; usually about 0.3

Cost

Engineering - Discrete Product Manufacturing

- **Manufacturing Philosophies**

Computer-Aided Process Planning (CAPP)	Concurrent Engineering	Group Technology
• Goal is to "automatically generate" the process plan to produce the component from the component drawings and specifications	• a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support	• a manufacturing philosophy that identifies and exploits the underlying sameness of component parts and manufacturing process

Cost

Engineering - Discrete Product Manufacturing

- **Manufacturing Philosophies**

Lean Manufacturing	Just-in-Time	Material Requirements Planning (MRP)
• philosophy to shorten lead times, reduce costs, and reduce waste • not "mean" manufacturing, rather it is a long-term continuous improvement process	• requires that the supplies (raw materials) are delivered when required • inventory costs are theoretically driven to zero as there is no inventory	• system that uses bills of material, inventory and open order data, and master production schedule information to calculate requirements for materials

Cost

Engineering - Discrete Product Manufacturing

- **Manufacturing Philosophies**

Supply Chain Management (SCM)	Total Quality Management
• complex products • integration of different components from a variety of suppliers • Parts arrive when required • suppliers get involved in the design process • information is shared – delivery status, payment schedules, etc. • Goal is to reduce inventory, time-to-market, and costs, and improve quality	• involves a leadership philosophy, organizational structure, and working environment • fosters and nourishes a personal accountability and responsibility for quality • drives continuous improvement in products, services, and processes

Cost

Engineering - Discrete Product Manufacturing

- **Basic Cost Relationships**
  - Prime Cost

    = direct material cost + direct labor cost

    + direct engineering cost + direct expenses
  - Manufacturing Cost

    = prime cost + factory expense
  - Production Cost

    = manufacturing cost + admin. expenses

Cost

Engineering - Discrete Product Manufacturing

- **Basic Cost Relationships**
  - Total Cost = production cost
    + marketing, selling, and distribution costs
  - Selling Price = total cost + mark-up (profit and taxes)

Cost – Equipment, Parts and Tools

Equipment Value Categories

1. **Replacement Cost New (new equipment cost)**
   - Reproduction cost:
     - the cost of a new identical item
   - Replacement cost:
     - the cost of a new item having the same or similar function
   - Fair Value:
     - is the adjusted cost of a new item, giving consideration for the cost of similar items, and taking into account function and all standard adjustments and discounts to list price

Cost – Equipment, Parts and Tools

Equipment Value Categories

2. **Market Value (used equipment)**
   - Fair market value-in-place
     - reasonable price for an item which will remain in it's current location and operation
     - will bring 'highest value'
   - Fair market value-in-exchange:
     - reasonable price for the sale and removal of an item (retail value)
   - Orderly liquidation value:
     - probably price for the orderly liquidation (must sale) of all assets

Cost – Equipment, Parts and Tools

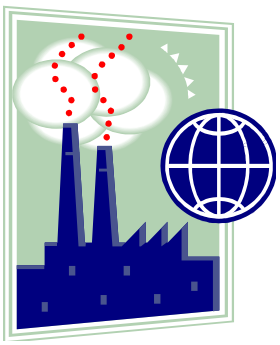
Equipment Value Categories

2. **Market Value continued…**
   - Forced liquidation value:
     - probably price for the quick sale (auction) of all assets
   - Salvage value / part-out value:
     - reasonable price recognizing the component value of parts of the equipment - used for repairs or replacement purposes
   - Scrap Value
     - the value of equipment that relates to the equipment's basic commodity value (ex. dollars per pound of copper)

Cost – Equipment, Parts and Tools

Residual Value

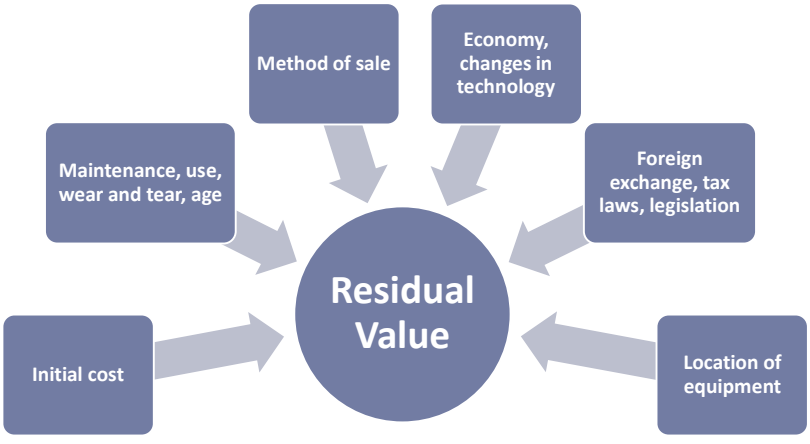
- **Definition**
  - Residual Value is the expected value at a specified future date, such as the end of a lease term or project,
  - Includes sale, re-lease, holdover rent, penalties, damage, litigation, etc.



Cost – Equipment, Parts and Tools

Residual Value

- **Variables affecting Residual Value**



Cost – Equipment, Parts and Tools

Residual Value

- Several types of indices are published and are available for purchase by trade associations, insurance companies, appraisal companies, and/or the government
  - **Machine-Specific**
    - devoted strictly to that type of equipment being valued
    - highest reliability
  - **Industry Specific**
    - based on a 'group of items' which represent a typical manufacturing plant or operation in a certain industry
    - less reliable

Cost Exercise

Questions: Materials, labor, Engineering & Equip.

- Complete questions 11 through 18
- Questions 19 & 20 for home study

Section 2A: Basic Cost Economics

Basic Cost Economics Outline

Introduction

- Definition of Cost Economics
- Key Types of Costs

Basic Cost Economics Outline

Basic Concepts

- Changes in Costs
- Techniques for Calculating Depreciation
- Straight Line Method (SL)
- Double Declining Balance (DDB)
- Techniques for Economic Analysis
- Net Present Worth
- Capitalized Costs
- Benefit-Cost (B/C) Ratio
- Activity-Based Cost Management
- Accounting Systems vs. ABC/M

Basic Cost Economics

Cost Economics

Definition

- The evaluate of how economic costs impact projects by understanding key concepts and using analysis techniques.

Basic Cost Economics

Key Types of Costs

Opportunity Costs	• The foregone benefit by choosing one option over another
Sunk Costs	• Funds already spent by the virtue of past decisions
Book Costs	• The value of an item as reflected in a the company's books
Incremental Costs	• The cost differences between various alternatives

Basic Cost Economics

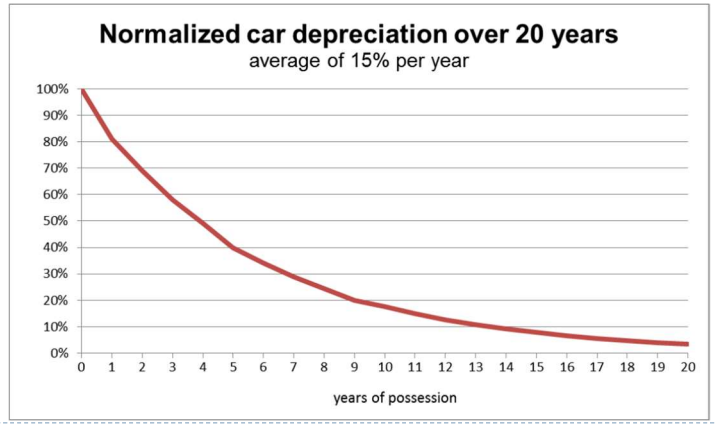
Changes in Costs

Global Economics	• Inflation, Money Supply, Exchange Rates, Demand-Pull Inflation, Cost-Push Inflation, Deflation, Escalation, Currency Variation
Government Cost Impacts	• Taxes, Value Added Tax (VAT), Effective Tax Rates, Marginal Tax Rates, Investment Tax Credits, Depreciation

Basic Cost Economics

Depreciation

- Depreciation in accountancy is the reduction in the value of an asset over time, due in particular to wear and tear.



Basic Cost Economics

Techniques for Calculating Depreciation

- **Straight Line Method (SL)**
  - Method of depreciation whereby the amount to be recovered (written-off) is spread uniformly over the life of an asset
  - Takes the original cost less the salvage value divided by the number of years of life by the formula
- **Formula:**

$$D = (C – S) \div N$$

Where: D = depreciation charge
C = asset original cost
S = salvage value
N = asset depreciable life (years)

Basic Cost Economics

Techniques for Calculating Depreciation

- **Double Declining Balance (DDB)**
  - Applies a constant depreciation rate to the assets' declining value
- **Formula:**

$$D = (2 \div N) \times (C - BV_t - 1)$$

Where: D = depreciation charge

C = asset original cost

BV = Book value at a given year

N = asset depreciable life (years)

Basic Cost Economics

Techniques for Economic Analysis

- **Net Present Worth**
  - the system of comparing proposed investments, which involves discounting at a known interest rate, in order to choose the alternative having the highest present value
- **Formula:**

$$\mathbf{P = F (1 + I)^{-n}}$$

Where: P = present value or present worth

F = future value or future worth

I = interest rate

n = number of compounding periods or asset life

Note: Future Value, $F = P (1 + I)^{n}$

Basic Cost Economics

Techniques for Economic Analysis

- **Capitalized Costs**
  - In some cases, problems have an infinite analysis period, such as the need for a highway or dam
  - The Capitalized Cost (CC) represents the present sum of money that needs to be set aside now, at some interest rate, to yield the funds required to provide the service indefinitely
- **Formula:**

$$CC = P + A \div I$$

Where: CC = Capitalized Cost
P = present value or present worth
A = annual amount
I = interest rate

Basic Cost Economics

Techniques for Economic Analysis

- **Benefit-Cost (B/C) Ratio Analysis Method**
  - involves the simple comparison between benefits and costs of a proposed action
  - if the ratio is greater than one, the project is viable
  - comparisons can be made between projects to select those projects with the highest B/C ratio
- **Formula:**

$$\text{B/C Ratio} = \frac{\text{Benefit}}{\text{Cost}}$$

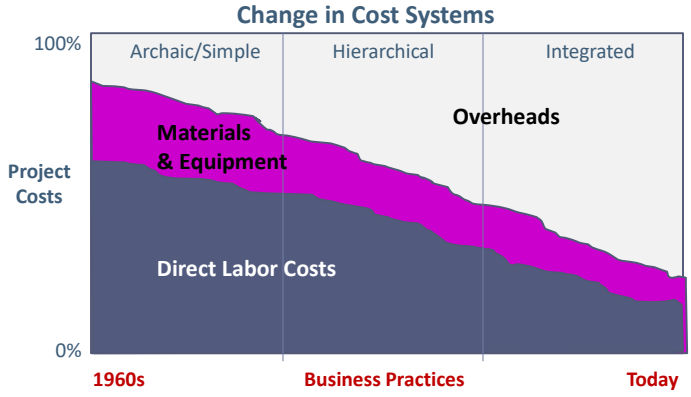
Basic Cost Economics

Activity-Based Cost Management (ABC/M)

- **What Changed?**
  - Indirect Costs are displacing Direct Costs
    - Why? The expansion in diverse product lines and types of sales and distribution channels has caused complexity requiring more indirect costs to manage the complexity
    - Better cost management systems are required to ensure business sustainability

Basic Cost Economics

"Change in the Role of Overhead Costs"



Basic Cost Economics

Activity-Based Cost Management (ABC/M)

- **Expenses versus Costs**

Expenses	Costs
• when cash is paid out by a company • Example: paying wages	• the calculated usage of the expense spending • Example: crane usage

Basic Cost Economics

Accounting Systems vs. ABC/M

- **Traditional Accounting Systems**
  - around for decades, tend to make arbitrary cost allocations, which have led to misleading information and poor decision making
- **ABC/M systems**
  - use a cost assignment model which has resulted in their general use and acceptance
  - transforms spending expenses on resources into "calculated costs" of work activities and processes and then into products, service-lines, channels, and customers

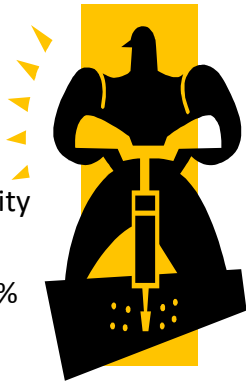
Basic Cost Economics

ABC/M vs. General Ledger

	ABC/M	General Ledger
Activity Descriptions:	Uses action-verb grammar convention	Uses nouns
Coding:	Chart of 'Activities'	Chart of 'Accounts'
Organization:	'Cost Assignment Network' by business or work processes (work-centric)	Department or cost centers mapped to hierarchical org chart
Details:	What it was spent for	Amount spent
Claims:	Costs are isolated	Costs buried
Benefits:	More accurate cost reporting More suited to analysis Used to forecast costs Drives process improvement and productivity	

Basic Cost Economics

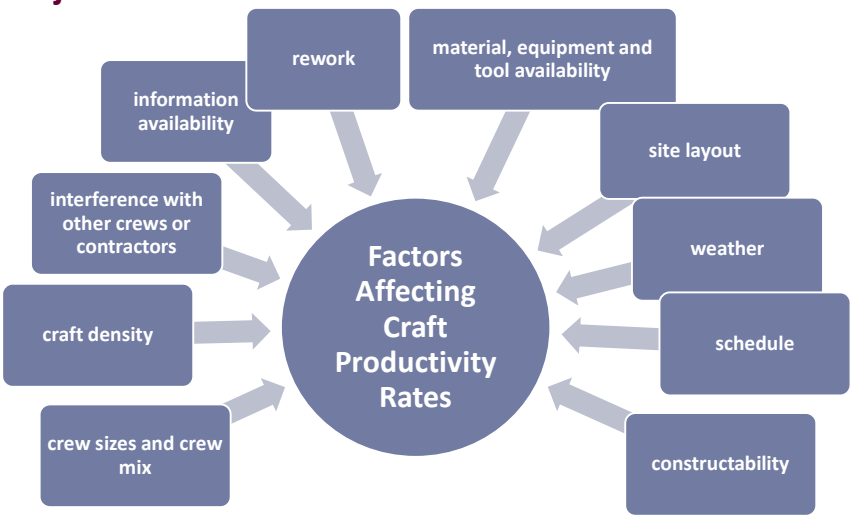
Project labor Cost Control



- **Construction labor Costs**
  - the 'most variable' element of the project construction budget
  - labor cost control is paramount to profitability
- **Pareto's Law**
  - "80% of project costs are determined by 20% of the elements"
- **Three components of labor costs:**
  - Installed Quantities
  - Production Rates
  - Wage Rates

Basic Cost Economics

Project labor Cost Control



Basic Cost Economics

Project labor Cost Control

- **Cost Coding / Work Breakdown Structure (WBS)**
  - A construction project is complex and must be broken into controllable parts (WBS)
  - The WBS is the classification of each project element along activity levels
  - The WBS must be carefully constructed and documented
    - 'Each step' of an installation process should be captured (makes data collection more difficult)

Basic Cost Economics

Project labor Cost Control

- **Cost Coding / Work Breakdown Structure (WBS)**
  - Activity outputs (progress) are measured and compared to the resources expended (actuals)
  - A construction project may have hundreds of cost codes
  - "The project team must consistently use the correct cost codes for inputs and outputs"

Basic Cost Economics

Project labor Cost Control

- **Construction labor Inputs:**
  - Dollars and work hours
- **Construction labor Outputs:**
  - Cubic meters of excavation
  - Tons of steel erected
  - Linear feet of pipe or wire pulled
  - Number of electric terminations or piles placed
- **Why are such a large number of measurements required in construction output?**
  - No common unit of measure

Basic Cost Economics

Project labor Cost Control

- **'Cardinal Rule' of labor Cost Control**
  - "The cost of the control techniques must be less than the money saved by using the cost control techniques"
- **The accuracy of cost coding work hours is improved by the following:**
  - training all personnel in the use of cost codes
  - checking timesheets for correct cost codes before recording in the cost control system
  - developing and maintaining a well documented WBS

Basic Cost Economics

Project labor Cost Control

- **Feedback Loop**
  - As construction activities proceed,
  - both actual dollars (or work-hours)
  - and actual progress are measured
  - The actual performance is compared to the budgeted/planned performance
  - Concentrates corrective efforts on activities whose actual performance deviate from the budget (negative deviation)
  - The effectiveness of the corrective action is monitored by this feedback loop

Section 2B: Cost Estimating

Cost Estimating Outline

Introduction

- Definition of Cost Estimating
- Purpose/Objective

Cost Estimating Outline

Basic Concepts

- Estimate Preparation
  - Basic Steps
  - Estimate Accuracy
- Estimate Classifications
- Common Estimating Methodologies
  - Conceptual Estimating
    - End-Product Units Method
    - Physical Dimension Method
    - Capacity Factor Method
    - Ratio or Factored Method
    - Parametric Estimating

Cost Estimating Outline

Basic Concepts

- Common Estimating Methodologies
  - Deterministic Estimating
    - Steps to Prepare an Estimate
    - Allowances
    - Quantity Take-offs
    - Estimate-Schedule Integration
    - Contingency
    - Risk Analysis
    - Structuring the Estimate
    - Estimate Reviews
    - Estimating Resources
    - Operating Costs

Cost Estimating

What is Cost Estimating?

- Cost Estimating
  - the predictive process used to quantify, cost, and price the resources required by the scope of an investment option, activity, or project

Cost Estimating

Cost Estimate

- Purpose and/or Objective:
  - determine the economic viability
  - evaluating between alternatives
  - establishing the budget
  - providing a basis for cost and schedule control

Cost Estimating

Estimate Preparation

- **Basic Steps:**
  - understand the scope of the project and/or activities to quantify the resources required
  - apply costs to the resources
  - apply pricing adjustments
  - organize the output in a structured way that supports decision-making
- **Estimate Accuracy**
  - "Estimate accuracy tends to improve as the level of project definition improves"

Cost Estimating

Estimate Classifications

- **AACE Identifies Five Classes of Estimates:**
  - A Class 5 Estimate is associated with the lowest level of project definition (or project maturity)
  - A Class 1 Estimate is associated with the highest level of project definition
- **The Characteristics which distinguish the Class of Estimate:**
  - degree of project definition
  - end usage of the estimate
  - estimating methodology
  - estimating accuracy
  - effort required to produce the estimate.

Cost Estimating

Generic Cost Estimate Classification Matrix

	Primary Characteristic	Secondary Characteristic		
Estimate Class	**Level of Project Definition**	**End Usage**	**Methodology**	**Expected Accuracy Range**
Class 5	0% to 2%	Concept Screening or Feasibility	Judgment or Stochastic	-50% / +100%
Class 4	1% to 15%	Study or Feasibility	Stochastic (involves guess work)	-30% / +50%
Class 3	10% to 40%	Budget Estimate, Authorization or Control	Primarily Deterministic, some Stochastic	-20% / +30%
Class 2	30% to 70%	Control Estimate or Tendering (Bids)	Primary Deterministic	-15% / +20%
Class 1	50% to 100%	Check Estimate or Tendering	Deterministic	-10% / +15%

Cost Estimating

Two Common Estimate Methodologies

1. **Conceptual (Order of Magnitude) Estimating:**
   - Involve simple or complex modeling (or factoring) based on relationships between costs and design-related parameters
   - Somewhat subject to conjecture (guess work or gut feel)
   - require significant data-gathering (historical costs) to develop accurate ‘factors’ (cost/capacity)
   - Little actual estimate preparation time (less than an hour)

Cost Estimating

Two Common Estimate Methodologies

2. **Deterministic (Detailed) Estimating:**
   - Requires a high degree of precision in the determination of quantities, pricing, and the completeness of scope definition
   - Requires a large effort during the actual preparation of the estimate (several weeks or months)
   - More Accurate

Cost Estimating

Specific Conceptual Estimating Methods

- End-Product Units Method
  - Uses historical data from similar projects to relate the end-product units (capacity units) of a project to its construction costs
  - Allows an estimate to be prepared
  - relatively quickly
  - Applicable when estimating the cost
  - of a hotel, hospital, construction camp
  - or parking garage when average
  - historical costs per unit can be applied

Cost Estimating

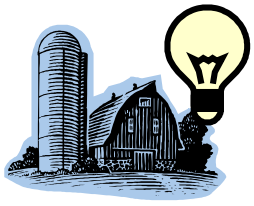
Specific Conceptual Estimating Methods

- Physical Dimensions Method
  - Uses historical information from comparable facilities
  - Uses physical dimensions (length, area, volume, etc.) as the driving factor
  - Example: a building estimate may be based on costs per square feet/meters; pipeline estimate based on costs per kilometers of pipe

Cost Estimating

Specific Conceptual Estimating Methods

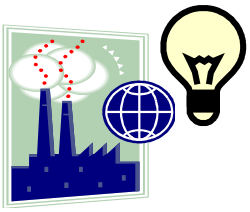
- Capacity Factor Method
  - The cost of a new facility is derived from the cost of a similar facility of a known (but usually different) capacity
  - The ratio of costs between two similar facilities is equal to the ratio of their capacities taken to an exponential factor (scaling or capacity factor)



Cost Estimating

Specific Conceptual Estimating Methods

- Ratio or Factored Methods
  - Used when the total cost of an item or facility can be reliably estimated from the cost of a primary component
  - Commonly used for process and chemical plants, where the cost of the specialized process equipment makes up a significant portion of the total project cost



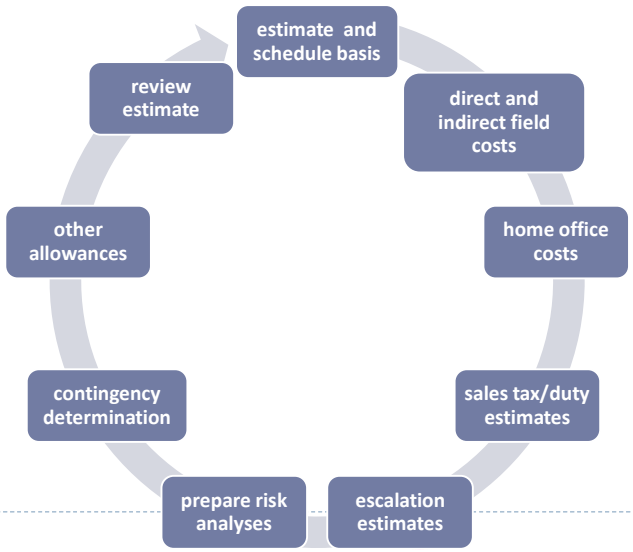
Cost Estimating

Specific Conceptual Estimating Methods

- Parametric Estimating
  - Uses sophisticated estimating algorithms, or cost estimating relationships, that are 'highly probabilistic' in nature
  - Complex spreadsheets or computer models are developed
  - Can be as accurate as definitive estimates

Cost Estimating

Typical Steps in Preparing a Detailed Estimate



Cost Estimating

Deterministic (Detailed) Estimating:

- Estimate Allowances:
  - often included in a detailed estimate to account for the predictable but un-definable costs associated with project scope
  - 'often' (but not always) included in the estimate as a percentage of some detailed cost component
  - Some typical examples are:
    - design allowance for engineered equipment
    - material take-off allowance
    - overbuy allowance
    - unrecoverable shipping damage allowance
    - allowance for undefined major items, etc.

Cost Estimating

Deterministic (Detailed) Estimating:

- Quantity Take-offs
  - Process of quantifying the material and labor quantities associated with the project
  - involves a detailed examination of the engineering drawings and deliverables
  - The quantities of like items are summarized according to the control structure (WBS) of the project
- Estimate-Schedule Integration
  - Required as project schedule may impact labor productivity as well as labor and material pricing

Cost Estimating

Deterministic (Detailed) Estimating:

- Contingency
  - Amount added to an estimate to allow for items, conditions, or events for which the effect is uncertain but will likely result in additional costs
  - Estimated using statistical analysis or judgment based on past experience
  - Contingency generally 'Excludes':
    - Major scope changes
    - Extraordinary events (war or natural disaster)
    - Management reserves
    - Escalation and currency effects

Cost Estimating

Deterministic (Detailed) Estimating:

- Risk Analysis
  - A risk management process which includes the quantification of the effect of all uncertainty (risks) on the project
  - Usually done by quantifying each risk's probability of occurrence and potential severity of impact
  - The impact may be expressed as 'a range of values', or with a 'confidence level', or as a 'probability distribution'

Cost Estimating

Deterministic (Detailed) Estimating:

- Structuring the Estimate
  - To maintain some kind of order in the estimate (and later in project execution), it is necessary to segregate costs into various categories:
    - Material vs. labor vs. subcontracts
    - direct costs vs. indirect costs vs. home office costs
    - concrete vs. structural steel vs. piping vs. other disciplines
    - Large projects will often use work breakdown structures (WBS) and resource breakdown structures (RBS) as components of the overall coding structure

Cost Estimating

Deterministic (Detailed) Estimating:

- Estimate Reviews
  - The estimate should be:
    - evaluated for quality or accuracy
    - reviewed to ensure all required information is present
    - presented in a way that is understandable to all project team members and client personnel
  - A structured (if not formal) estimate review process should be a standard practice for all estimating departments

Cost Estimating

Deterministic (Detailed) Estimating:

- Estimating Resources
  - engineering and design information
  - material cost and pricing information
  - labor workhour charts, labor productivity information, labor wage rates, composite crew mixes, etc.
  - Estimating guideline and procedure manuals
  - In-house cost history manuals
  - Special cost studies (ex. scaffolding studies)
  - Engineering and design manuals and specifications
  - Estimating software - can enhance the accuracy and consistency and reduce time

Cost Estimating

Deterministic (Detailed) Estimating:

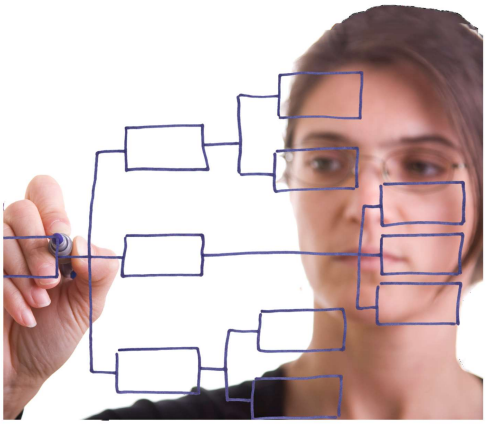
- Estimating Operating Costs
  - The preferred basis to estimate operating costs is
  - 'Annual Basis'.
    - 'damps out' seasonal variations
    - considers the operating time of equipment
    - adapts to less-than-full capacity operations
    - readily includes the effect of periodic large costs (scheduled maintenance, catalyst changes, etc)
    - directly usable in profitability analysis
    - readily convertible to the other bases such as daily cost and unit-of-production

Cost Exercise

Questions: Basic Economic Costs & Estimating

- Complete questions 21 through 32.

Section 3A: Planning



Planning Outline

Introduction

- Definition of Planning
- Major Elements of Planning

Planning Outline

Basic Concepts

- Planning Process Steps
- Planning Objectives
  - Establishing well Defined Project Objectives
- Cost & Schedule Baselines
- Work Breakdown Structure
- Project Execution Plan
- Scope Control
- Construction Planning

Planning

Planning Definition

- Making decisions ‘now’ with the intent to influence the ‘future’
- Process of establishing objectives and building policies, procedures, and programs to achieving these objectives
- A detailed scheme, program, or method worked out beforehand for the accomplish an objective:
  - “ A Plan of Attack”
- Looking Ahead
- Is proactive vs. reactive management
- Both an art and a science

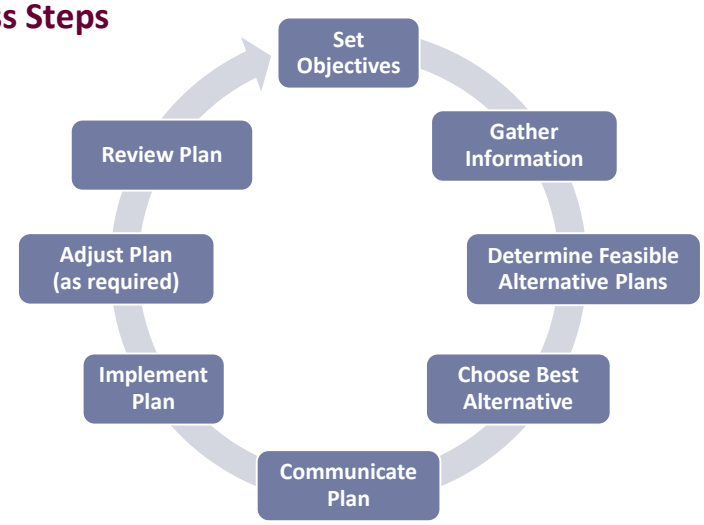
Planning

Major Elements of Planning

1. Summarized Goals & Scope of Work
2. Time Planning
3. Cost Planning
4. Resource Planning
5. Quality Planning
6. Post Completion Review
7. Planning for Change (Contingency Planning)

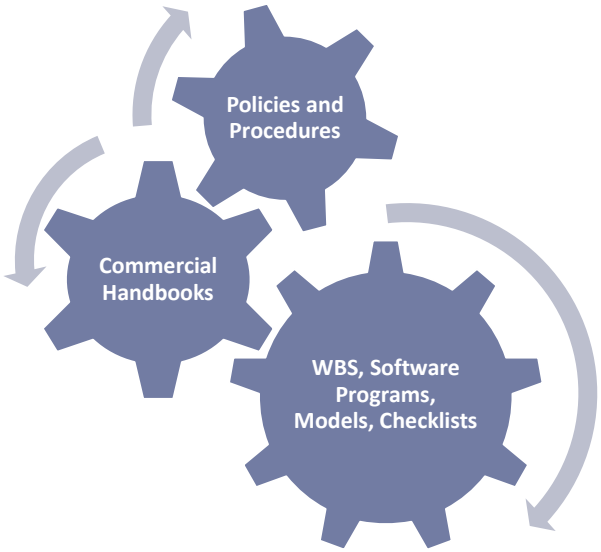
Planning

Process Steps



Planning

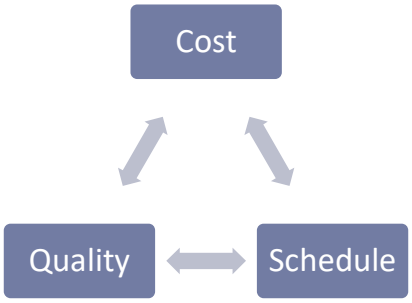
Planning Tools



Planning

Planning Objectives

- Project Objectives
  - Will be a compromise between quality, cost, and schedule



Planning

Planning Objectives

- Establishing Well-Defined Project Objectives
  - Need to be 'specific' and prioritized
  - Documented
    - Project Execution Plan (PEP)
  - Well communicated to all stakeholders
  - Maintained as the project changes
  - Examples:
    - client satisfaction (measureable)
    - cost and schedule criteria
    - technology transfer, etc.

Planning

Project Baselines

- Cost & Schedule Baselines
  - Define the software programs and processes to be used
  - Propose a WBS (work breakdown structure)
  - Cost Estimate
  - Define levels of cost and scheduling reporting
  - Define project milestones
  - Define a risk program
  - Develop a contingency management program

Planning

Work Breakdown Structure

- Progressive hierarchical breakdown of the project into smaller pieces
- It organizes and defines the 'total scope' of the project
- Normally includes a facility breakdown as well as components within the facilities
- Each descending level represents an increasingly detailed definition of the project work

5200 = Warehouse Foundations

5300 = Warehouse Electrical

5310 = Warehouse Electrical – Cable Pulling

5320 = Warehouse Electrical – Cable Terminations

Planning

Project Execution Plan

Major Categories in a PEP (Project Execution Plan)		
Project Scope • Design basis, facility descriptions, interface points, project locations, etc.	**Execution Strategy** • Procurement plan, contracting strategy, quality plan, organization charts, etc.	**Schedule** • Critical paths, weather windows, union climates, shutdown considerations, etc.

Planning

Scope Management

- Scope Control Program
  - Determine a Design Control Point
    - where the design is frozen
  - Document all changes
  - Establish a comprehensive design change and/or trending program
  - Good team communication with all stakeholders
  - Quantify cost and schedule impacts
  - Implement ‘value engineering’ initiatives
  - Incorporate ‘constructability studies’ into designs

Planning

Construction Planning

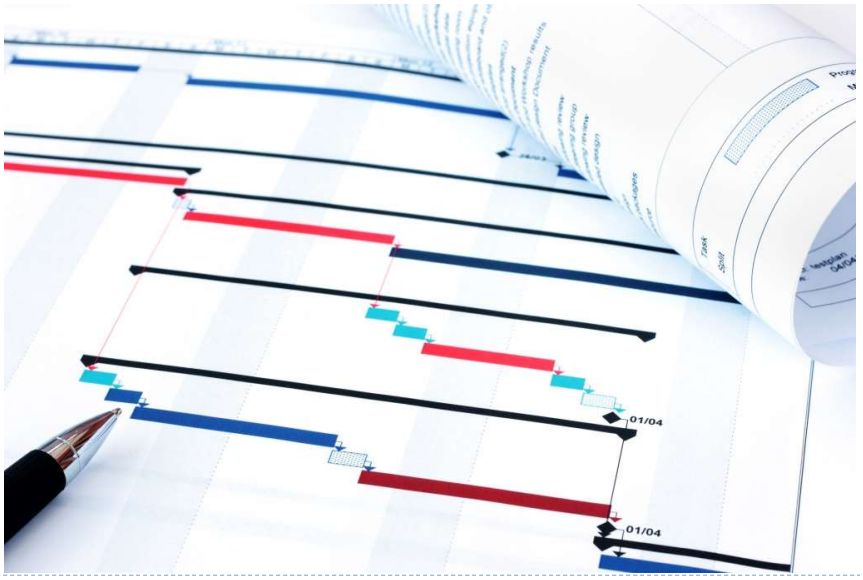
- Constructability
  - An evaluation of the physical sequence of construction work to produce the most desirable result
    - Incorporate cost and schedule impacts
  - Consider technology options and installation methods
    - Examples: pre-cast concrete or modularization

Planning

Construction Planning

- Construction Pre-Planning
  - Resource Planning (resource loaded schedules)
  - Build construction management organization chart
  - Solve site access issues
  - Identify supporting infrastructure requirements
    - temporary utilities, communications, camps, etc.

Section 3B: Scheduling



Scheduling Outline

Introduction

- Definition of Scheduling
  - Schedule Development
- Purpose

Scheduling Outline

Basic Concepts

- Critical Path Method (CPM)
- Schedule Elements
- Network Calculations
- Gantt Chart
- Schedule Development Process
- Schedule Compression

Scheduling

Definitions

- Scheduling
  - Conversion of a project action plan into an operating timetable
  - A structured picture of the visualized project construction
- Schedule Development
  - an iterative process:
    - determines planned start and finish dates for project activities
    - continues throughout the project as work progresses

Scheduling

Purpose

- Schedule is used to establish:
  - Timing of objectives
  - Sequence of activities
  - Resource requirements
  - Cash flow requirements
  - Benchmarks
  - Basis for performance
  - An early warning system
  - Allow logical decisions to be made for project
  - Develop milestone schedules
  - Facilitate communication throughout the project

Scheduling

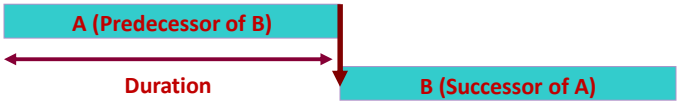
Critical Path Method (CPM)

- A network analysis technique to determine:
  - the minimum total project duration
  - amount of scheduling flexibility (float)
- Early start and finish dates are calculated by means of a forward pass
- Late start and finish dates are calculated by means of a backward pass
- Activities with the same Early and Late dates are called Critical

Scheduling

Schedule Elements

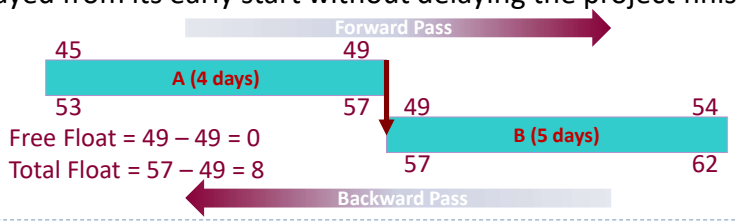
- **Activity** - the Basic element into which a project is subdivided for scheduling a CPM network
- **Duration** - the total number of work periods required to complete an activity
- **Predecessor** - an activity that must occur before another activity
- **Successor** - activity that must occur after another activity



Scheduling

Schedule Elements

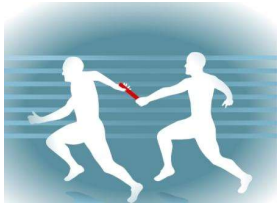
- **Early Dates** - early start and early finish
- **Late Dates** - late start and late finish
- **Free Float** - the amount of time an activity can be delayed without delaying the early start of any immediately following activities
- **Total Float** - the amount of time that an activity may be delayed from its early start without delaying the project finish



Scheduling

Schedule Elements

- **Different types of relationships among the activities:**
  - Finish-to-Start (FS)
  - Start-to-Start (SS)
  - Finish-to-Finish (FF)
  - Start-to-Finish (SF)



- **Lag:** An offset or delay from an activity to its successor. Lag can be positive or negative.

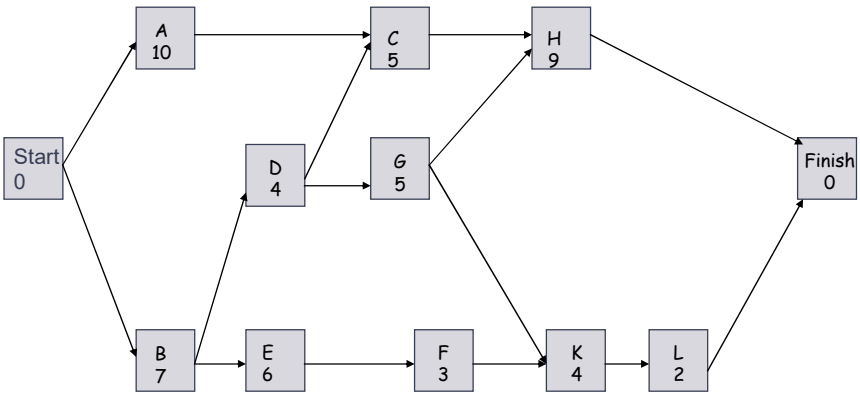
Scheduling

Network Calculation

- **Process Steps:**
  - 1 Start & 1 Finish
  - Start at time zero
  - EF(activity) = ES(activity) + Duration
  - ES(successor) = EF(predecessor) + Lag (if any)
  - Forward pass to calculate project earliest finish
  - Backward pass to calculate late dates
  - Calculate total float of activities
  - Determine critical path

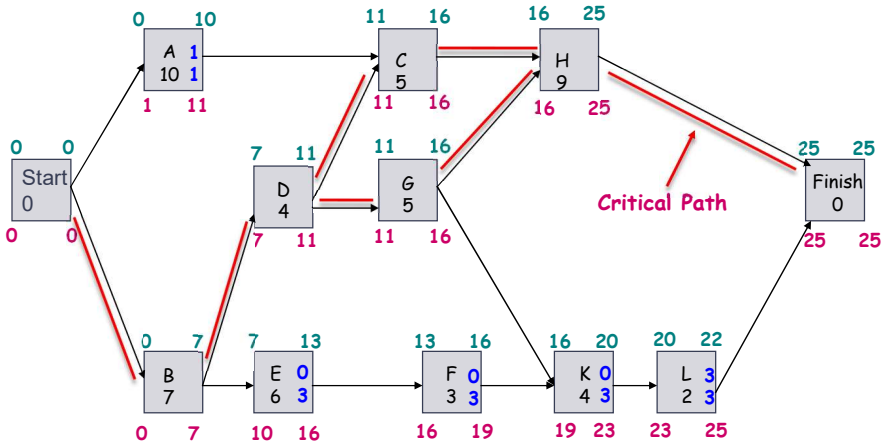
Scheduling

Sample Network Calculation



Scheduling

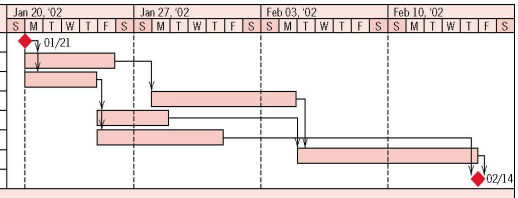
Sample Network Calculation



Scheduling

Sample Gantt Chart

ID	Task Name	Duration	Start	Finish	Predecessors
1	Start	0 days	01/21/2002	01/21/2002	
2	a	5 days	01/21/2002	01/25/2002	1
3	b	4 days	01/21/2002	01/24/2002	1
4	c	6 days	01/28/2002	02/04/2002	2
5	d	2 days	01/25/2002	01/28/2002	3
6	e	5 days	01/25/2002	01/31/2002	3
7	f	8 days	02/05/2002	02/14/2002	4,5
8	Finish	0 days	02/14/2002	02/14/2002	6,7



Project
Date: 01/21/2002

Task

Milestone

Scheduling

Schedule Development Process (AACE TCM)

- Plan for Schedule Planning and Development
- Identify Activities
- Develop Activity Logic
- Estimate Durations
- Establish Schedule Requirements
- Allocate Resources
- Optimize Schedule
- Establish Control Basis
- Review and Validate
- Document and Communicate
- Submit Schedule Deliverables
- Maintain Schedule

Scheduling

Schedule Compression

- Used when normal duration and sequence of activities cannot complete the project within available time
- Activities can be crashed or overlapped (compressed)
- Determine the activities to be compressed (on critical path)
- Start compression of the activity with the lowest cost slope
- Check if the critical path is changed
- Continue until intended duration is reached

Scheduling Exercise

Questions:

- Complete questions 33 to 44.

Section 4: Progress and Cost Control

Outline

- Introduction
  - Terminologies
  - Formulas
- Basic Concepts
  - Periodic vs. Cumulative Curves
  - WBS and Work Packages
  - Planned Value (PV)
  - Actual Costs (AC)
  - Earned Value (EV)
    - Progress Measurement
- Earned Value Analysis
  - Variances and Performances
- Forecasting

Introduction

Earned Value Management (EVM)

- An integrated planning and control tool
- A cost and schedule control system
- A forecasting tool
- A system for periodic performance measurements
- A system to compare original with target

Introduction

EVM can answer:

- Is the project ahead of or behind schedule?
- When is the project likely to be completed?
- Is the project currently under or over the budget?
- How much is the project under or over the budget at the end?
- What is the remaining work likely to cost?
- What is the entire project likely to cost?
- How efficiently resources are used?
- How efficiently are project team using their time?

Introduction

Key Terminologies

- PV: Planned Value
  - BCWS: Budgeted Cost of Work Scheduled (=PV)
- EV: Earned Value
  - BCWP: Budgeted Cost of Work Performed (=EV)
- AC: Actual Cost
  - ACWP: Actual Cost of Work Performed (=AC)

Introduction

Key Terminologies

- SV: Schedule Variance
- SPI: Schedule Performance Index
- CV: Cost Variance
- CPI: Cost Performance Index
- TCPI: To-Complete Cost Performance Index
- PC: Percent Complete
- BAC: Budget at Completion
- EAC: Estimate at Completion
- ETC: Estimate to Completion
- VAC: Variance at Completion

Introduction

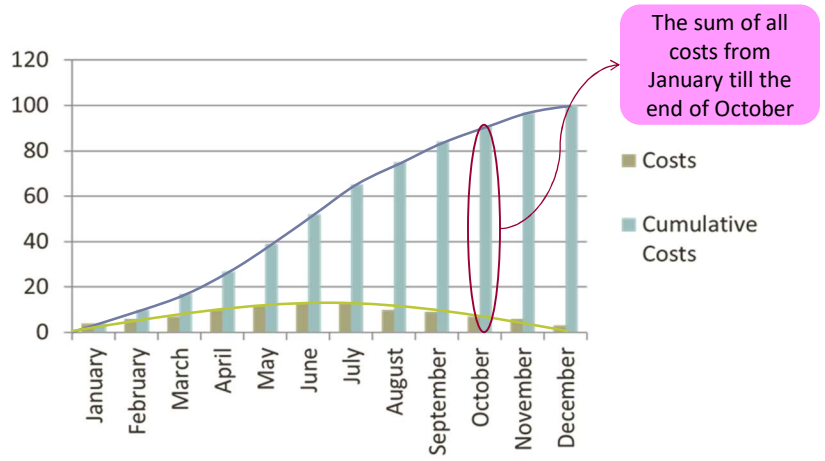
Key Formulas

- SV = EV – PV
- SPI = EV/PV
- CV = EV – AC
- CPI = EV/AC
- TCPI = (BAC - EV)/(BAC- AC)
- VAC = BAC - EAC
- EV = PC × BAC

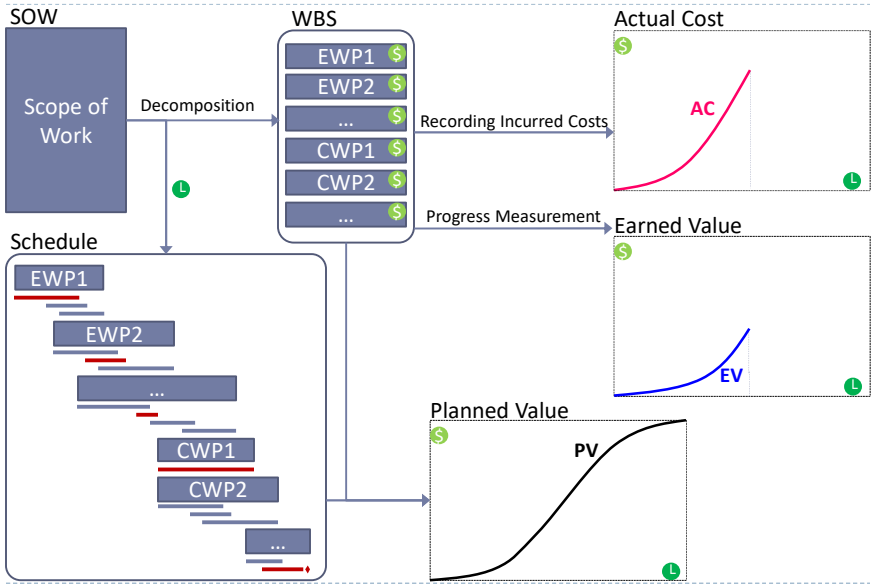
Basic Concepts

Periodic vs. Cumulative Curves

- S Curve



Basic Concepts



Exercise

Questions 45 to 48: Basic Concepts

Earned Value (EV)

Progress Measurement

- Units Completed
- Incremental Milestones
- Start-Finish Milestones
- Supervisor Opinion
- Cost Ratio
- Weighted or Equivalent Units

Progress Measurement

Units Completed

- For measuring repeated production of easily measured pieces of work
- Examples:
  - Meter of wire pulling
  - Inch-dia. of pipe welding
  - Cubic meter of concrete pouring
  - Square meter of finished surface

Progress Measurement

Incremental Milestones

- For measuring any work that includes sequential subtasks
  - Installing a major equipment
- "Rules of Credit": Segmenting a task into subtasks and assigning each an increment of progress

Progress Measurement

Incremental Milestones

- Example: An Engineering Work Package (Generating drawings)

Incremental Task	Incremental Progress	Cumulative Progress
Started	10%	10%
Preliminary Draft	30%	40%
Internal Review	25%	65%
Client Review	15%	80%
Client Comments Implemented	10%	90%
Client Approval	10%	100%

Progress Measurement

Incremental Milestones

- Example: A Construction Work Package (Installing a vessel)

Incremental Task	Incremental Progress	Cumulative Progress
Equipment received	15%	15%
Setting completed	20%	35%
Alignment completed	15%	50%
Internals installed	25%	75%
Testing completed	15%	90%
Accepted by owner	10%	100%

Progress Measurement

Start-Finish Milestones

- Applicable to work packages that lack readily definable intermediate milestones, or those for which the effort to estimate the increments is very difficult
- A percent complete is arbitrarily assigned to the start, and the finish is always 100%
- Examples:
  - Start: 0%, Finish: 100%
  - Start: 30%, Finish: 100%
  - Start: 50%, Finish: 100%

Progress Measurement

Supervisor Opinion

- Personal judgment of percent complete
- A subjective approach, thus not very precise
  - Optimistic vs. pessimistic judgment
- Suitable for minor, less important tasks
- Examples:
  - Dewatering
  - Landscaping
  - Temporary construction

Progress Measurement

Cost Ratio

- Work packages or tasks that include a long period of time and continuous effort
- Also known as Level of Effort (LOE)
- Percent Complete = Actual costs ÷ Forecast at completion
- Examples:
  - Project Management
  - Project Controls
  - Quality Management

Progress Measurement

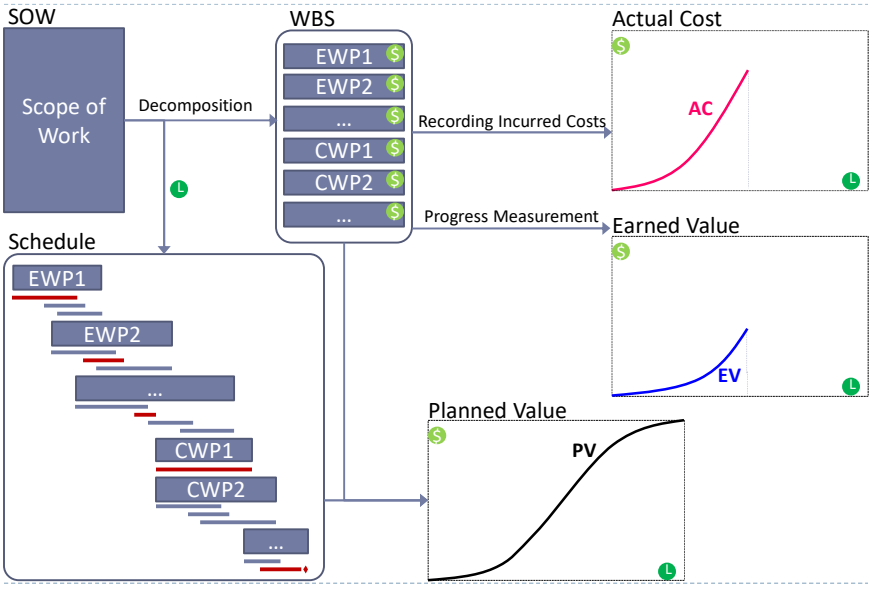
Weighted (Equivalent) Units

- Work packages that include a long period of time and several overlapping tasks, each with a different unit of measurement
- Example: Structural steel erection

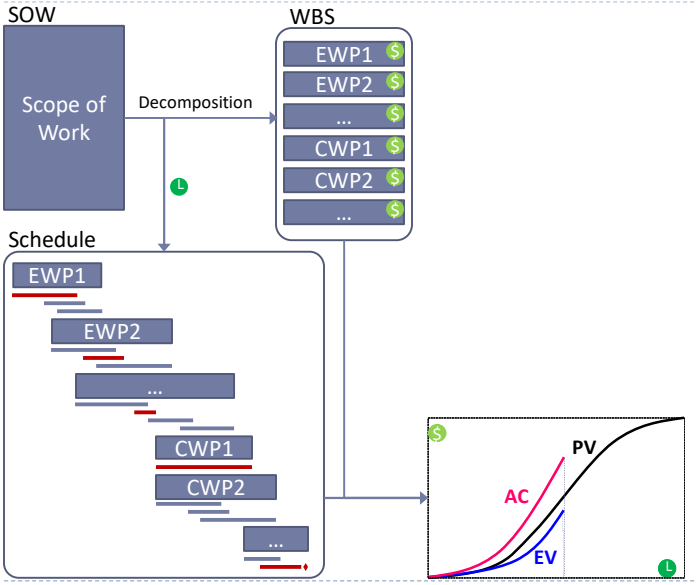
Exercise

Questions 49 to 51: Progress Measurement

Big Picture

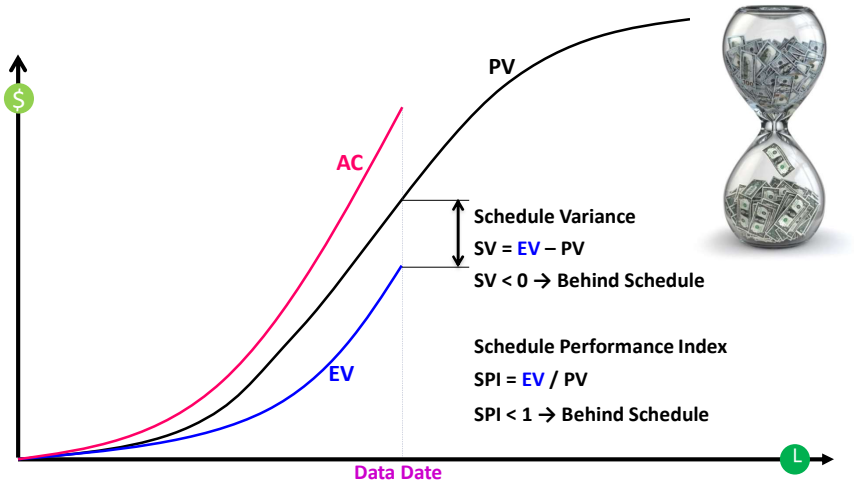


Big Picture



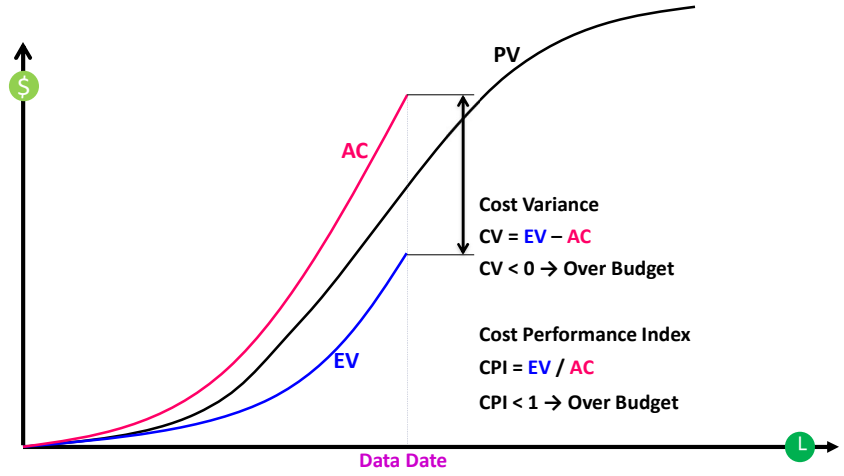
Earned Value Analysis

Schedule Variance and Performance



Earned Value Analysis

Cost Variance and Performance



Earned Value Analysis

Using PV, EV and AC

- Measuring EV against PV provides information about schedule
- Measuring EV against AC provides information about cost
- Measuring PV against AC provides no valuable information!

Earned Value Analysis

Example:

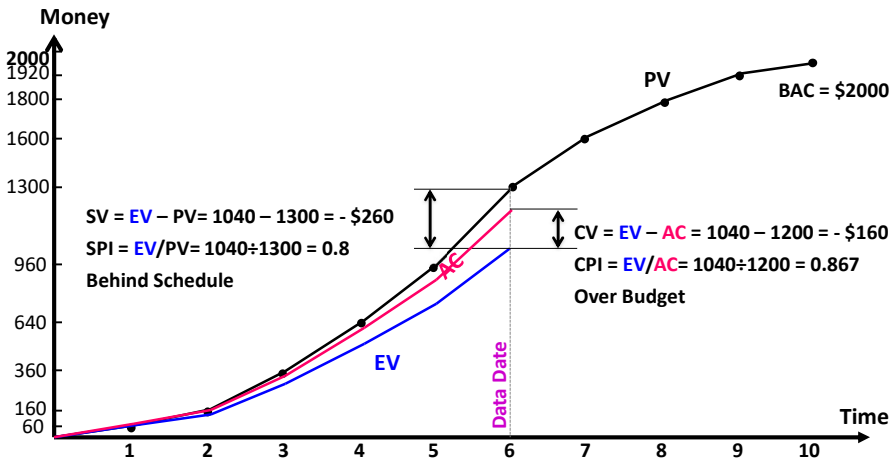
- Completing 100 deliverables in 10 months
- Estimated production cost = $20 per deliverable
- Data date at the end of month 6

Month	1	2	3	4	5	6	7	8	9	10
No. of deliverables (planned)	3	8	18	32	48	65	80	90	96	100
PV	60	160	360	640	960	1300	1600	1800	1920	2000
No. of deliverables produced	3	7	15	26	39	52				
EV	60	140	300	520	780	1040				
AC	70	160	340	600	900	1200				

At the end of 6th month, 52 deliverables have been produced (PC = 52%). For this number of deliverables, $1040 had been allocated, but $1200 have been paid. The original plan was to produce 65 deliverables, i.e. $1300.

Earned Value Analysis

Example:



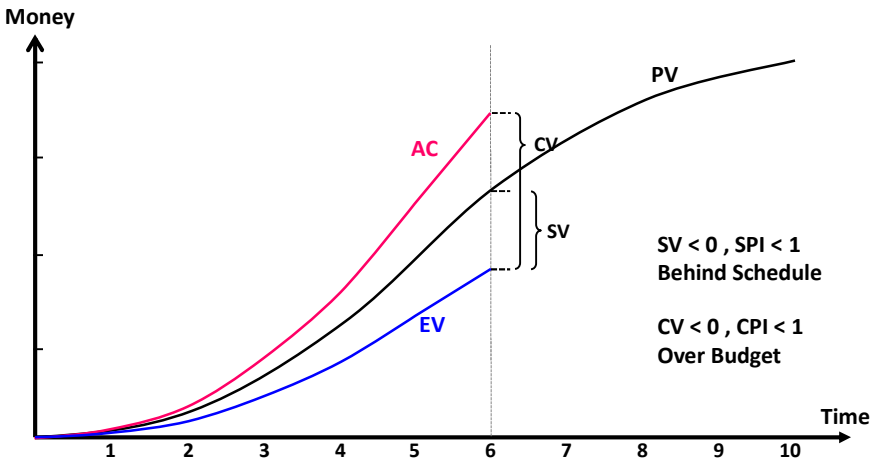
Interpreting EV Information

SV, SPI, CV, CPI

	SV>0 SPI>1	SV=0 SPI=1	SV<0 SPI<1
CV>0 CPI>1	Ahead of Schedule, Under Budget	On Schedule, Under Budget	Behind Schedule, Under Budget
CV=0 CPI=1	Ahead of Schedule, On Budget	On Schedule, On Budget	Behind Schedule, On Budget
CV<0 CPI<1	Ahead of Schedule, Over Budget	On Schedule, Over Budget	Behind Schedule, Over Budget

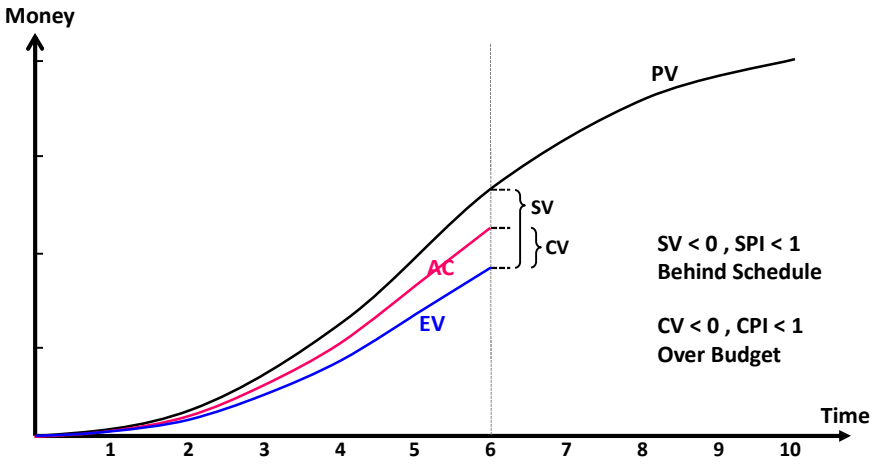
Interpreting EV Information

Case 1



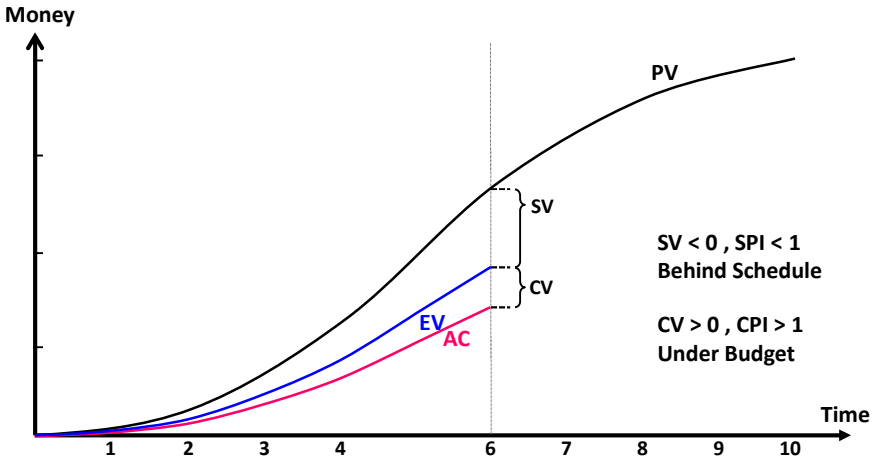
Interpreting EV Information

Case 2



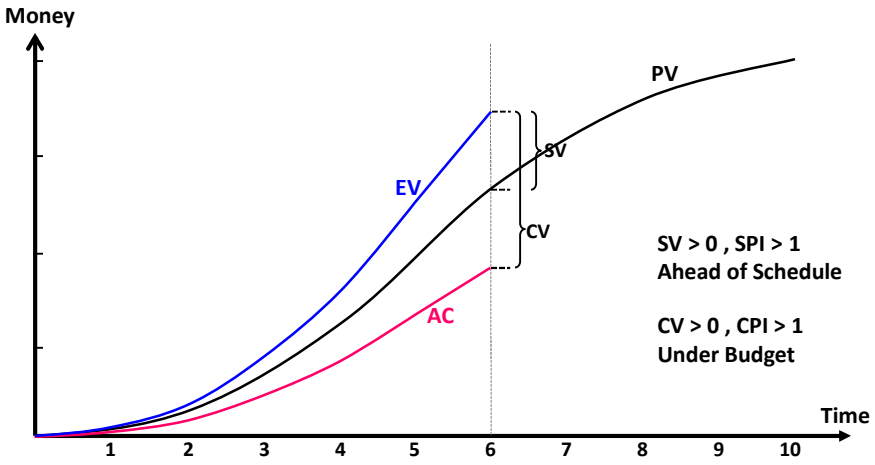
Interpreting EV Information

Case 3



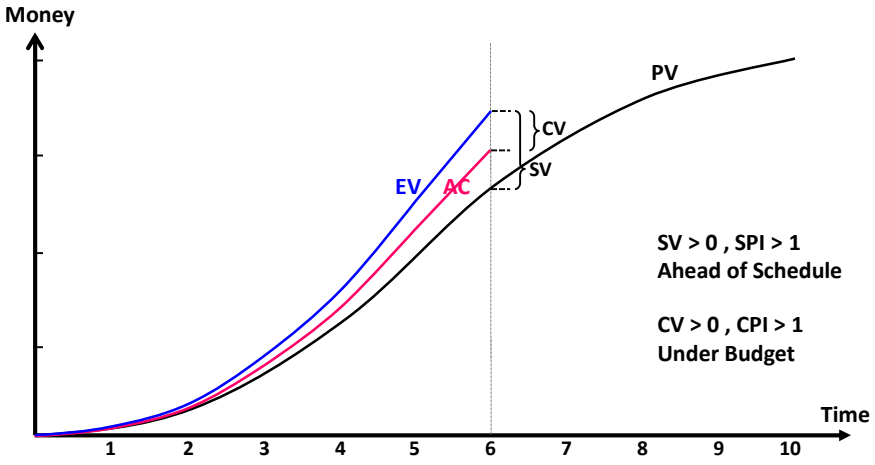
Interpreting EV Information

Case 4



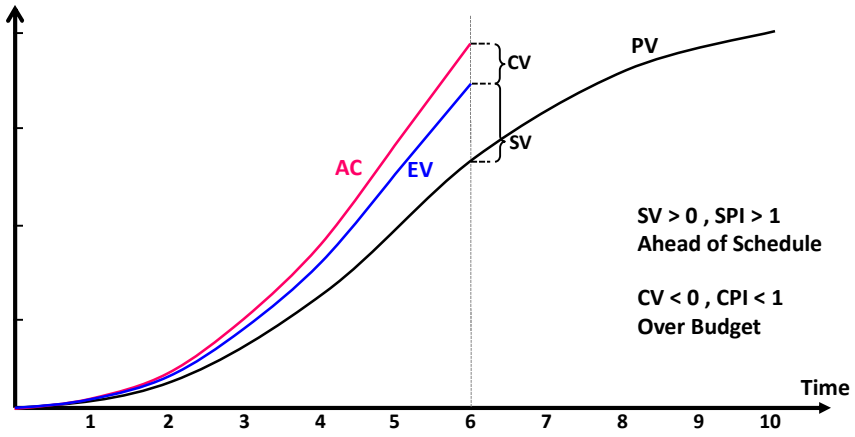
Interpreting EV Information

Case 5



Interpreting EV Information

Case 6



Exercise

Questions 52 to 59: Earned Value Analysis

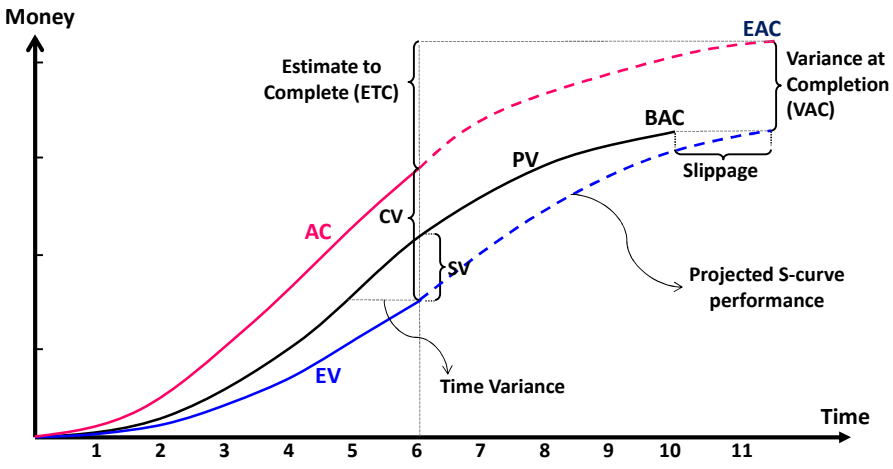
Forecasting

Benefits of EV

- EV enables statistical (probable) forecasting of:
  - Final cost results
  - Final schedule results
- EV gives an early warning on project performance
- From the 20% point fairly accurate Estimate at Completion (EAC) can be done
- Corrective action can be taken early

Forecasting

Projections, Variances and Slippages



Forecasting

Method 1: Rate of Progress

- Forecast rate of progress:

  EAC = BAC ÷ CPI or EAC = AC ÷ PC

- The assumption is that the project will keep the current CPI until the end

Forecasting

Method 2: Cost Variance

- Forecast costs or work hours:

  EAC = BAC + (AC – EV) or EAC = BAC - CV

- The assumption is that the project will keep the current CV until the end

Forecasting

Example:

- Completing 100 deliverables in 10 months
- Estimated production cost = $20 per deliverable
- Data date at the end of month 6

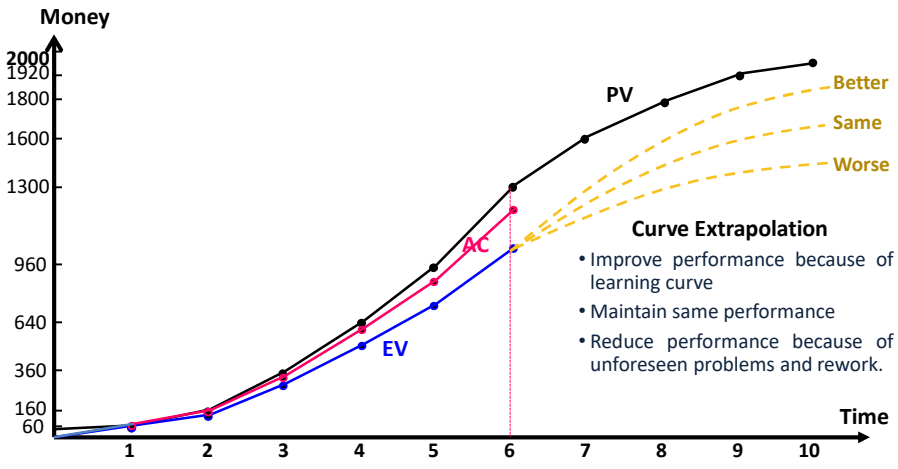
Month	1	2	3	4	5	6	7	8	9	10
No. of deliverables (planned)	3	8	18	32	48	65	80	90	96	100
PV	60	160	360	640	960	1300	1600	1800	1920	2000
No. of deliverables produced	3	7	15	26	39	52				
EV	60	140	300	520	780	1040				
AC	70	160	340	600	900	1200				

EAC=AC÷PC=1200÷0.52=2307

EAC=BAC+(AC–EV)
=2000+(1200–1040)=2160

Forecasting

Method 3: Curve extrapolation



Forecasting

To-Complete Performance Index (TCPI)

- TCPI is the calculated projection of cost performance that must be achieved on the remaining work to meet the budget at completion (BAC) or the estimate at completion (EAC)
- If BAC is valid, TCPI = (BAC – EV) ÷ (BAC – AC)
- If EAC is valid, TCPI =(BAC – EV) ÷ (EAC – AC)

Exercise

Questions 60 to 69: Forecasting

Final Notes

EVM vs. CPM

- The SPI and the critical path, when analysed together will accurately assess the project schedule performance
  - SPI<1 indicate overall activities slipping
  - Adding resources to catch up on non-critical activities may just waste money
  - SPI<1 on critical path activities indicate overall project schedule slipping

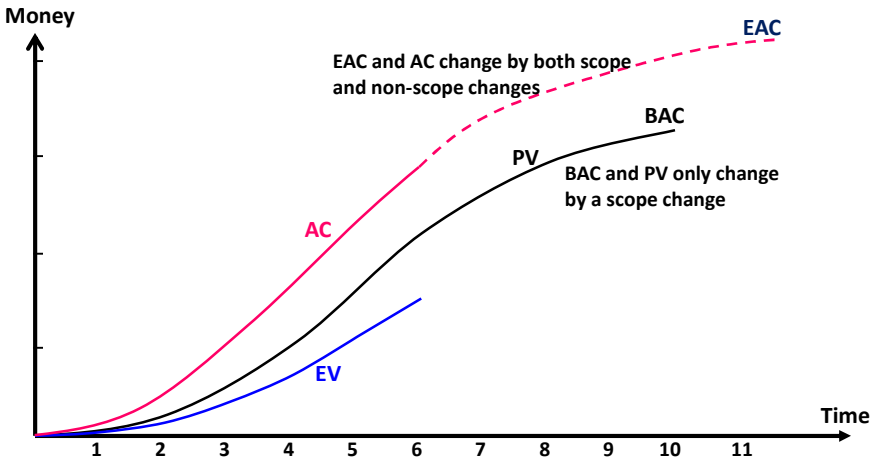
Final Notes

Variable Budget

- With a scope change, both EAC and BAC should be changed
- Budget at Completion (BAC) is the value of the original budget plus approved budget additions for scope changes, change orders, cardinal changes, etc.
- With a non-scope change, only EAC should be changed

Final Notes

Variable Budget



Final Notes

Productivity

- Numerical evaluation of total organizational performance is shown by success index (SI):
  - Success Index = net profit / total costs
- For a service organization:
  - Success Index = value of services rendered / costs of providing services

Section 5: Project Management

Project Management

Essential Factors for Successful Project Execution

- Cost Management
- Time Management
- Human Resources
- Communications

Project Management

Improvements

1968	• Critical Path Method (CPM)
1970	• Fast Track
1982	• Fast Track Trapezoidal Technique
1985	• Independent Construction Management
1990	• Partnering, Contracting Management
1990	• Total Quality Management (TQM)
1990	• Participative and Open Book Management
1990	• Design Quality Assurance – Value Engineering
1990	• Project Management Performance Measurement

Project Management

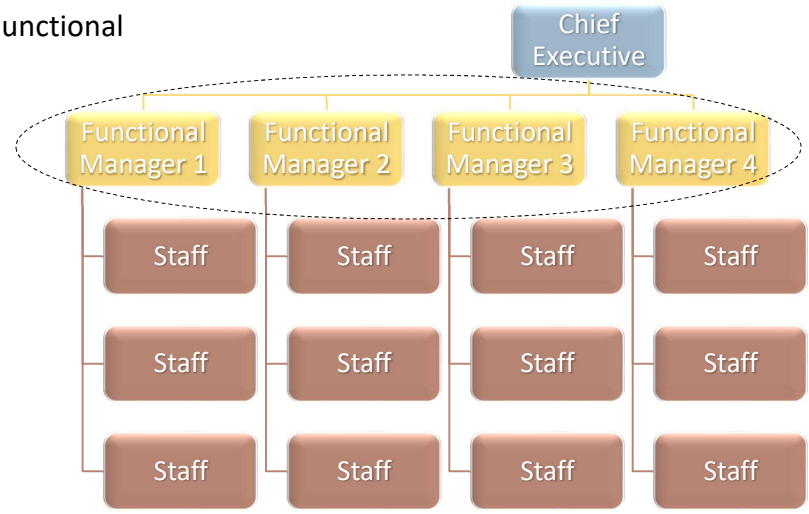
Types of Organizations

- Functional
- Project
- Matrix
  - Strong
  - Balanced
  - Weak

Project Management

Types of Organizations

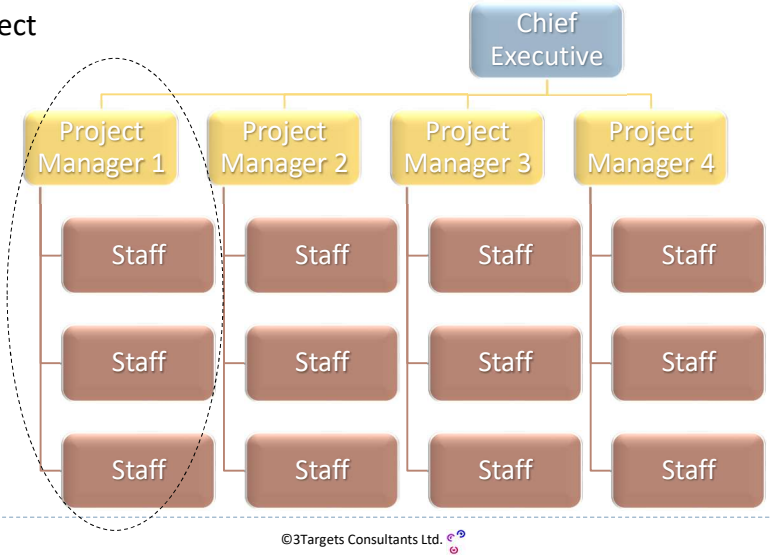
- Functional



Project Management

Types of Organizations

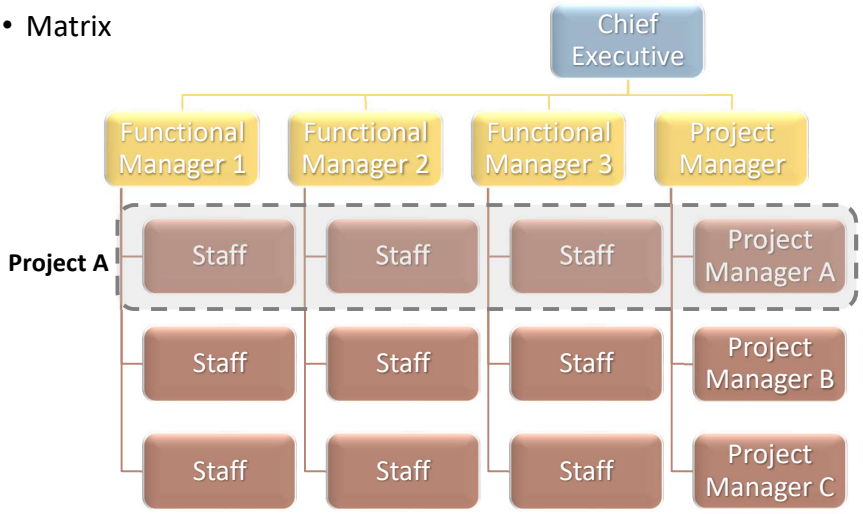
- Project



Project Management

Types of Organizations

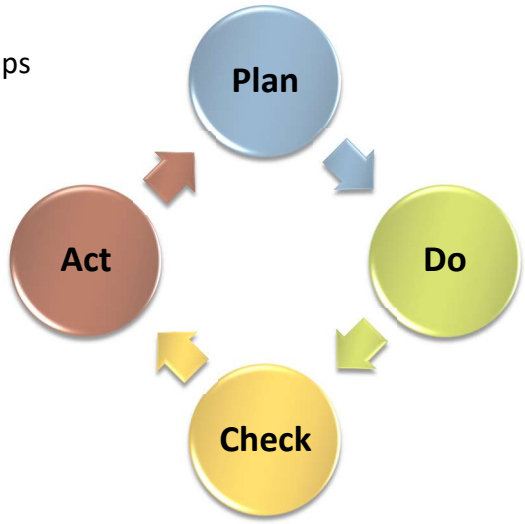
- Matrix



Project Management

Process

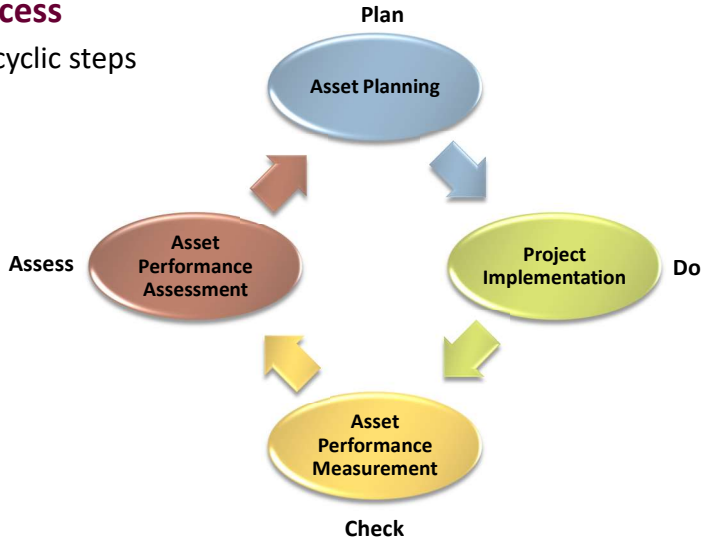
- 4 cyclic steps



Strategic Asset Management

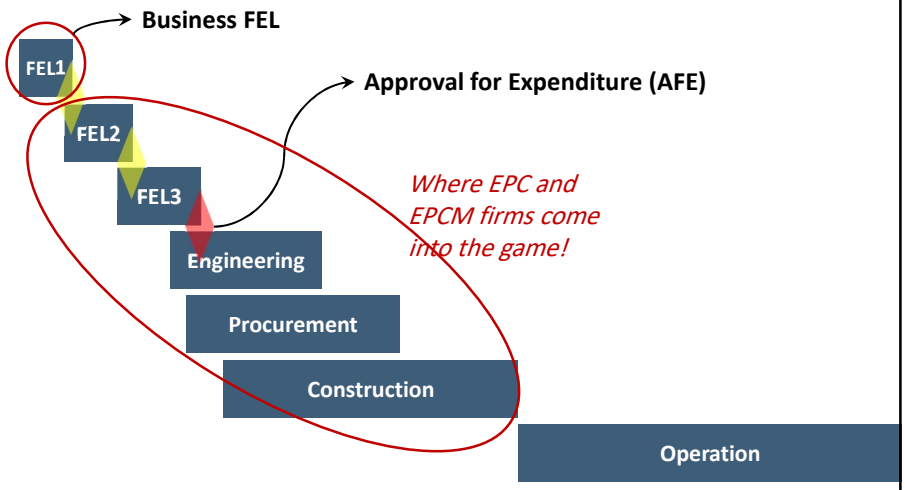
Process

- 4 cyclic steps



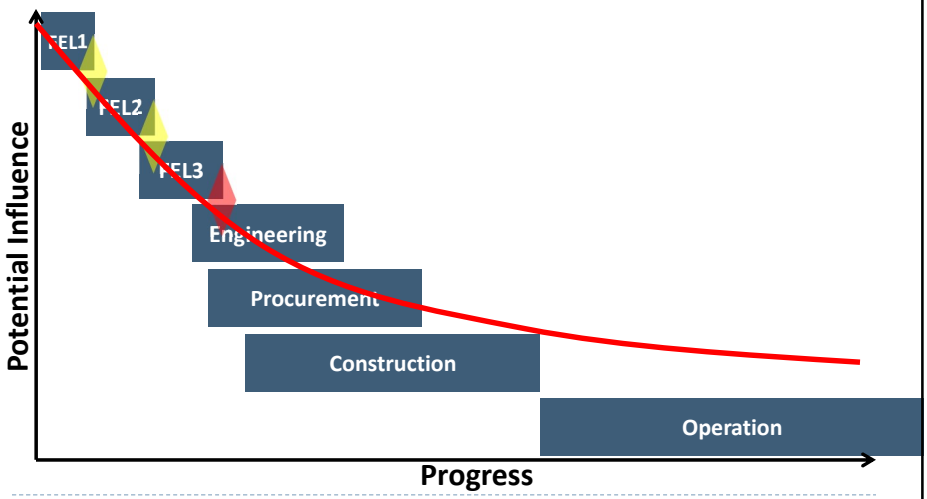
Strategic Asset Management

Phases and Gates



Strategic Asset Management

Influence Curve



Strategic Asset Management

Why Phases and Gates?

- The phases and gates approach is a structured way to project set-up and business planning
- Project phases were developed in response to poor project outcomes and need to supervise capital better
- It is an evolution from goal of making investment decision with the lowest possible investment/effort/cost to more predictable outcomes from the investment decision.

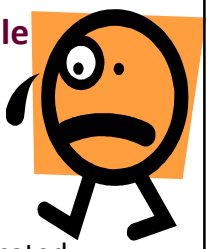
Project Management

Leadership and Management of Project People

- **Roles of a Project Manager:**
  - **Leader** - conceptualizes the vision and direction of the project and sales this vision to the team
  - **Manager** - ensures the project is completed on time, within budget, and at acceptable levels of performance
  - **Facilitator** - help others get their work done through the art of influencing others. Involves communication skills, conflict resolution, the ability to get resources and motivate both individuals and the team.
  - **Coach** - assists another person, either formally or informally, in various tasks related to professional growth and development

Project Management

Leadership and Management of Project People



- Manager Challenges
  - uncertain resource support
  - extreme time pressures
  - first-time challenges to solve unique and complicated problems
  - a wide variety of personnel and other resource interdependencies
  - challenges of obtaining resources from senior managers who may not totally support the project

Project Management

Leadership and Management of Project People

- Skills of a Successful Manager
  - apply both technical and managerial skills
  - motivate the team
  - create group cohesion
  - drive the team toward excellence
  - work with the emotional, intellectual, and physical challenges
  - think in terms of three dimensions – time, cost, and performance
  - manage conflict

Project Management

Leadership - Building Teams

- Key Components of Effective Team Building Programs:
  - Commitment to the cause
  - A coming together or 'togetherness'
  - Cost and schedule awareness
  - Job satisfaction
  - Quality performance
  - Recognition / Awards program

Project Management

Leadership - Building Teams

- Concerns or Considerations when Building Teams:
  - People coming from different locations and cultures
  - Varying levels of skills and expertise
  - Initially, little knowledge of project details
  - Learning curve will take time
  - Ongoing team building program
  - Budget for team building

Project Management

Motivation

- "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"

Project Management

Motivation

- Intrinsic Motivation
  - arises from a source within a team member
    - example: desire to obtain new skills
- Extrinsic Motivation
  - involves a force outside of the individual
    - Example: recognition from one's peers in a professional association or a sizeable pay increase
- Members of a high-performance team tend to be motivated by both sources

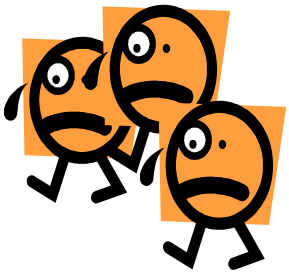
Project Management

Motivation Challenges

- Three Strong Forces and Trends:
  1. the continuing ongoing reductions in workforce numbers
  2. the unspoken contract between the employee and employer which has changed dramatically over the past 20 years
  3. the increase in the number of team members that are from different backgrounds and viewpoints

Project Management

Common Motivational Mistakes

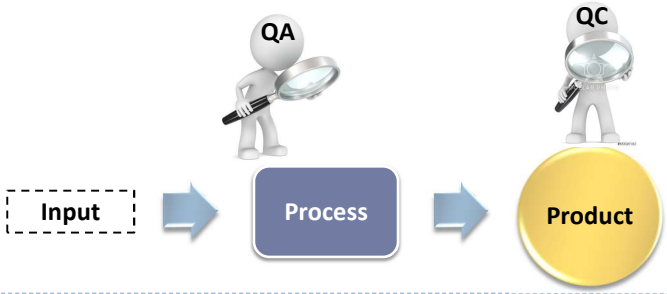


- what motivates me will motivate others
- people are motivated by money
- everyone wants a formal award
- team members are motivated by quotas
- the best leader is a strong cheerleader
- professional people do not need motivating
- people only need to be motivated if there is a problem
- everyone should be treated the same
- just find one thing that motivates each person and stay with it

Quality Management

Quality Assurance vs. Quality Control

- Quality Assurance (QA) is a set of activities for ensuring quality in the processes by which products are developed. It is a proactive quality process.
- Quality Control (QC) is a set of activities for ensuring quality in products. QC aims to identify (and correct) defects in the finished product. It is a reactive quality process.



Quality Management

Impact of Poor Quality

- **Sporadic deficiencies:** Periodically occur and are dealt with shortly after they happen. They involve adverse consequences like customer complaint or a missed delivery date.
- **Chronic deficiencies:** Chronic problems, in contrast, have usually existed for an extended period of time and may be accepted or tolerated by the organization as irresolvable.

Quality Management

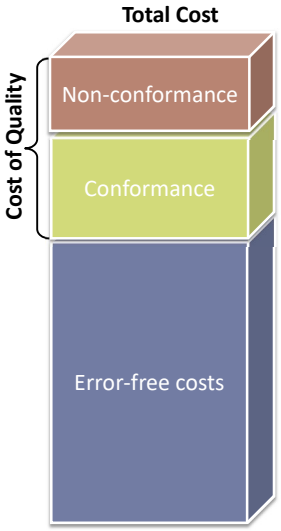
Three Managerial Steps (Juran Trilogy)

- Quality planning
  - Translating customer needs into characteristics of products and service lines (e.g., quality function deployment analysis).
- Quality control
  - Measuring quality levels and comparing them against desired levels (i.e., removing sporadic deficiencies).
- Quality improvement
  - Implementing incremental improvements to attain better levels of control (i.e., removing chronic deficiencies).

Quality Management

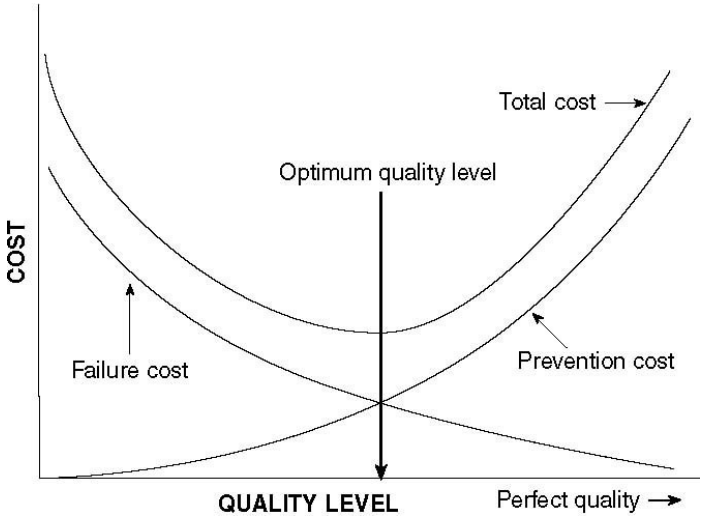
Quality Costs

- **Error-free costs:** Costs unrelated to planning of, controlling of, correcting of, or improving of quality. These are the did-it-right-the-first-time (nicknamed "dirtfoot") costs.
- **Cost of Quality (COQ):** costs that could disappear if all processes were error-free and if all products and services were defect-free.
  - **Costs of conformance:** Prevention costs
  - **Costs of non-conformance**: Failure costs



Quality Management

Quality Costs



Quality Management

Quality Authorities

- Quality Institutes providing “quality awards”
  - The Malcolm Baldrige National Quality Award (USA)
  - The European Foundation for Quality Management (EFQM)
  - The Deming Application Prize (Japan)

Contracts

Requirements of a Contract

- Offer
- Acceptance
- Legality of purpose
- Competent parties
- Consideration

Contracts

Mistakes in Contracts

- Mistakes that make the contracts defective
  - Mistakes as to the nature of transaction, identity of a party, identity or existence of the subject matter
- Mistakes that do not make the contracts defective
  - Mistakes as to value, quality, price, and terms of contract

Contracts

Types of Contract

- Fixed-Price/Lump-Sum
  - With economic adjustment
  - With incentives
- Fixed-Price/Unit-Price
- Cost Reimbursable (also known as Time and Material - T&M)
  - Cost Plus Fixed Fee (CPFF)
  - Cost Plus Incentive Fee (CPIF)
- Target (also known as Guaranteed Maximum Price – GMP)

Contracts

Lump Sum vs. Cost Reimbursable

Attributes	Lump Sum	Reimbursable
Contractor selection	Formal, Slow, Difficult	Subjective, Swift, Easy
Project definition	Extensive	Narrow
Owner's involvement	Little	High
Guarantee on final cost	High	Little
Project Risks	Contractor	Owner
Flexibility	Low	High

Contracts

Key Contract Clauses

- Audit
- Changes
- Delays
- Governing law
- Indemnification
- Insurance
- Force majeure
- Warranty
- Order of precedence (detail provisions over general provisions)
- Termination
- Dispute resolution

Contracts

Termination

- **Termination for convenience**: The owner decides, for their own reasons, to stop the job
- **Termination for default:** The contractor is in breach of contract, the owner terminates the contractor from the project and call upon the contractor's financial guarantees

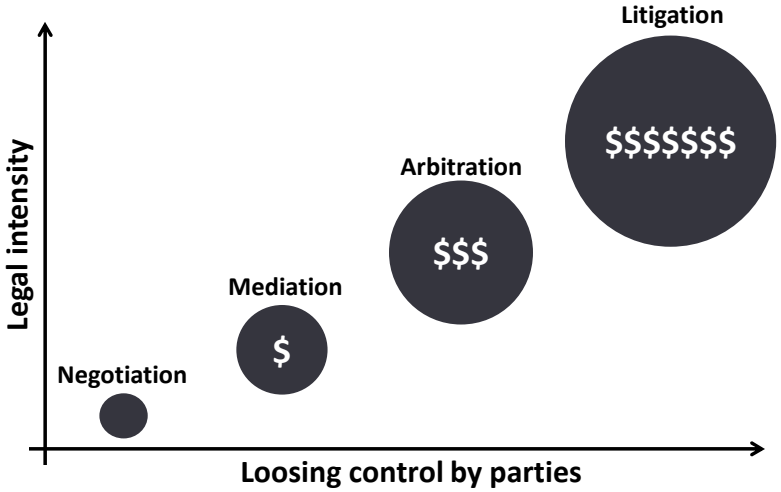
Contracts

Dispute Resolution Methods

1. **Negotiation:** Disputing parties negotiate to reach a solution
2. **Mediation:** An independent third party is appointed who makes non-binding recommendations to settle the dispute. Mediation is confidential, economical and voluntary.
3. **Arbitration:** 1 or 3 arbitrators are appointed, who make a decision which is binding. This could be expensive and the provisions are usually included in the contract.
4. **Litigation:** A complaint is filed with a court, and the final judgment of the court is binding. This is expensive and the outcomes could be unpredictable.

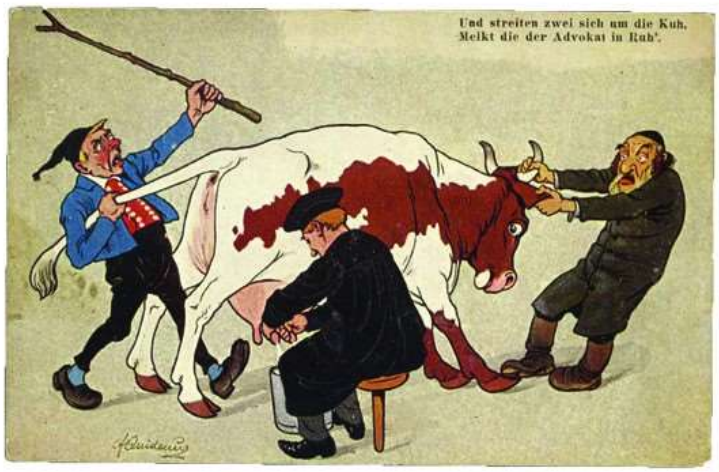
Contracts

Comparing Dispute Resolution Methods



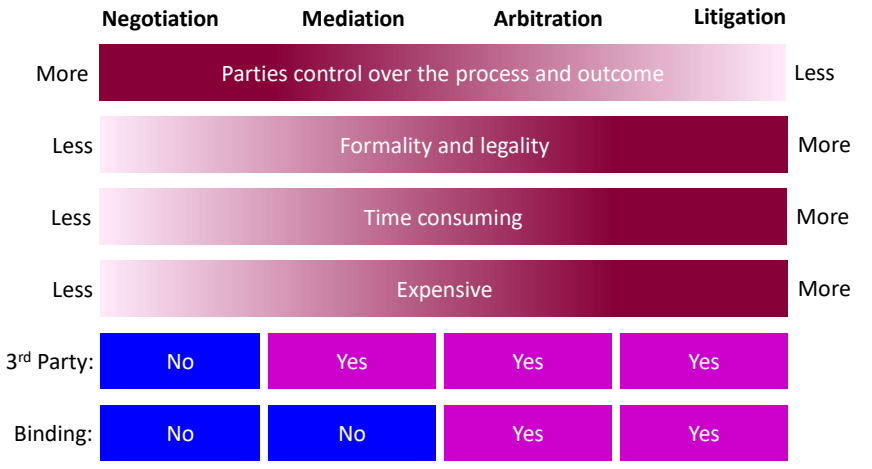
Contracts

As two fight over a cow, the lawyer milks it in peace



Contracts

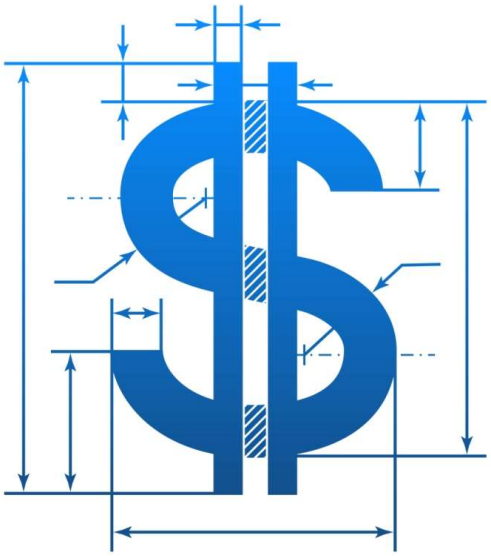
Comparing Dispute Resolution Methods



Exercise

Questions 70 to 77: Project Management

Section 6: Economic Analysis



Engineering Economics

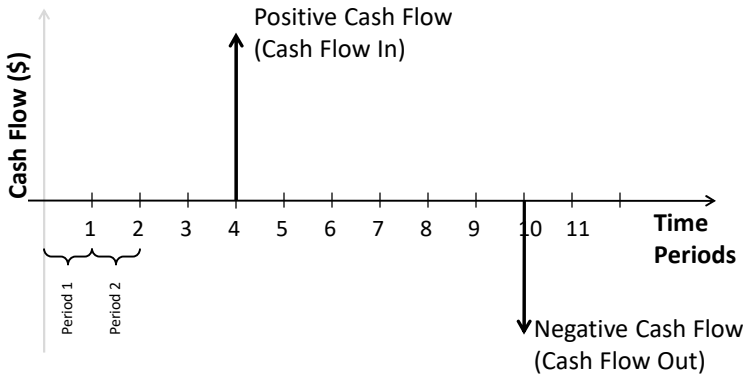
Time Value of Money

- Time value of money is the most important concept in engineering economics
- Value of money usually declines with time
- Equivalence: The ability to compare cash flows at different points in time
- Equivalence provides a common language for comparing present and future sums of money

Engineering Economics

Cash Flow Diagram

- A graph that summarizes the timing and amount of cash flows as they occur over time



Engineering Economics

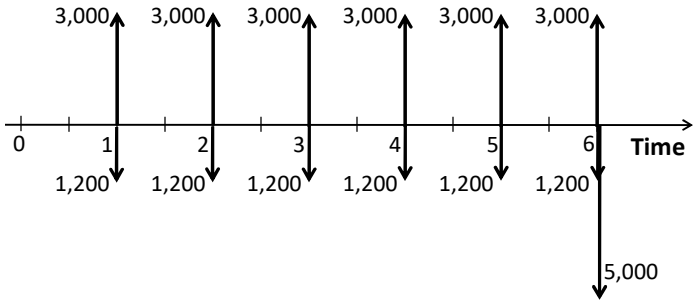
Cash Flow Diagram

- Horizontal axis shows time periods
- Vertical axis is not shown explicitly
- Vertical arrows show the amount and the direction of cash flows
- The end of period 1 is the beginning of period 2
- All transactions are assumed to occur at the end of periods

Engineering Economics

Cash Flow Diagram

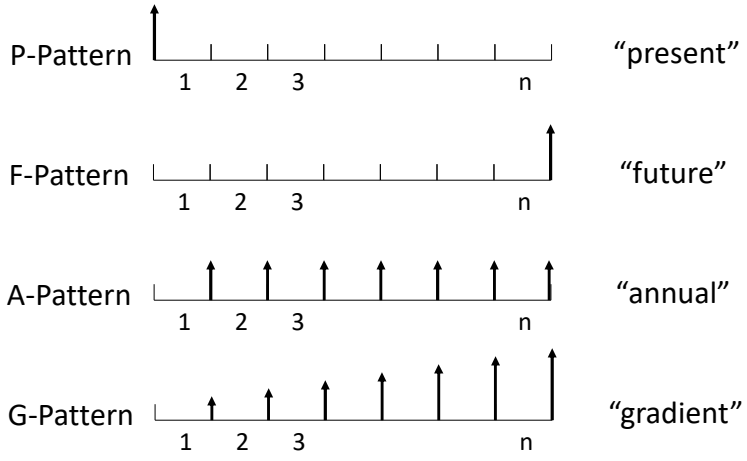
- Exercise: Draw a six-month cash flow diagram for a company with the following cash flows:
  - Monthly income: $3,000
  - Office space rent: $1200/month
  - Tax at the end of the 6th period: $5,000



Engineering Economics

Cash Flow Diagram

- Patterns



Engineering Economics

Cash Flow Models

- **Discrete:** All cash flows and their compounding occur at the end of time periods
- **Continuous:** Cash flows and their compounding occurs continuously over time
- We will follow the Discrete Model in this course

Discrete Compounding

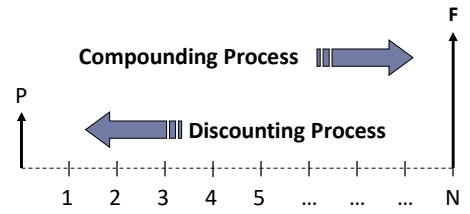
Principles of discrete compounding

- Compounding periods are of equal length
- Each disbursement and receipt occurs at the end of a period
- Annuities and gradients coincide with the ends of sequential periods.

Discrete Compounding

Single Cash Flow

- P=Present equivalent value
- F= Future equivalent value
- N= Number of Periods
- i= Interest Rate



$$F = P(1+i)^N \qquad P = \frac{F}{(1+i)^N}$$

Discrete Compounding

Single Cash Flow

- Compound amount factor: $(F/P,i,N) = (1+i)^N$ → "What is F, given P, i, and N?"
- Present worth factor: $(P/F,i,N) = 1/(1+i)^N$ → "What is P, given F, i, and N?"

Discrete Compounding

Example 1: Calculating F from P, i and N

- How much money will be in a bank account at the end of 20 years if $1000 are deposited today and the interest rate is 6% compounded annually?

$$(\mathrm{F/P, i, N}) = (1+\mathrm{i})^{\mathrm{N}}$$
$$\rightarrow F = 1000 \times (1+0.06)^{20}$$
$$\rightarrow F = 3207.1$$

Discrete Compounding

Example 2: Calculating i from P, F and N

- What must be the annual rate of return that a $1000 investment becomes $8000 after 10 years?

$$(\mathrm{F/P, i, N}) = (1+\mathrm{i})^{\mathrm{N}}$$
$$\rightarrow 8000/1000 = (1+i)^{10}$$
$$\rightarrow 8^{1/10} = 1+i$$
$$\rightarrow i = 0.231$$

Interest Rates

Interest Periods

- One year: The most commonly used interest period
- Semiannually: Twice per year
- Quarterly: Four times per year
- Monthly: 12 times per year
- Weekly: 52 times per year
- Daily: 365 times per year
- Continuous: Infinitesimally small periods

Interest Rates

Question: Which investment is better?

1. An investment with 12% per year interest compounded yearly
2. An investment with 1% per month interest compounded monthly

Interest Rates

Nominal Interest Rate

- The conventional method of stating the annual interest rate

$$i_s = r/m$$

- i_s : Interest rate for each sub-period
- r: Nominal interest rate for the full period (year)
- m: number of sub-periods
- Example:
  - Nominal interest rate of 12% per year compounded monthly is equal to 1% interest rate per month:
  - i_s = 12%÷12

Interest Rates

Effective Interest Rate

- Effective interest rate is the actual interest rate which is not usually stated and has to be calculated
- i_e is the interest rate for the full period (e.g. one year) that will yield the same amount as a nominal interest rate compounding at the end of each sub-period (e.g. month)

- $P(1+i_e) = P(1+i_s)^m \rightarrow$ **$i_e=(1+i_s)^m-1$**

Interest Rates

Effective Interest Rate

- Example: 18% interest compounded monthly is equal to 1.5% interest per month for 12 months and is equal to 19.56% interest compounded annually:

- $i_e=(1+i_s)^m-1 \rightarrow i_e=(1+0.015)^{12}-1 \rightarrow i_e= 0.1956$

- (F/P, 1.5%, 12) = (F/P, 19.56%, 1)

Interest Rates

Comparing Effective Interest Rates

- Example A:

Nominal Interest Rate	12%
Effective Interest Rate Compounded:	
Semiannually	12.36%
Quarterly	12.55%
Monthly	12.68%
Weekly	12.73%
Daily	12.75%
Continuous	12.75%

Interest Rates

Comparing Effective Interest Rates

- Example B:

Nominal Interest Rate	24%
Effective Interest Rate Compounded:	
Semiannually	25.44%
Quarterly	26.25%
Monthly	26.82%
Weekly	27.05%
Daily	27.11%
Continuous	27.12%

Interest Rates

Continuous Compounding

- $i_e = \text{Lim}_{m\to\infty}((1+r/m)^m-1) = e^r-1$

- Example: The cash flow of an investment company is continuously invested with a nominal interest rate of 50%. What is the effective interest rate by this investment?
  - $i_e=e^{0.5}-1= 64.9\%$

Interest Rates

Nominal vs. Effective Interest Rates

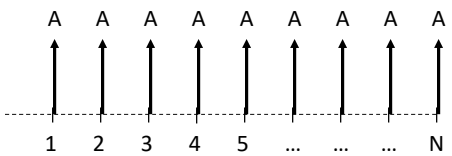
- When do nominal and effective interest rates become equal?

Discrete Compounding

Annuity

- Application: Converting a single future amount into a series of equal-sized payments over *N* equal periods with an interest rate *i*.
- Examples: Mortgage, lease payments, maintenance contract fees, etc.

Annuity over N periods



Discrete Compounding

Annuity

- Sinking fund factor:

$$(A/F, i, N) = \frac{i}{(1+i)^N - 1}$$

- Uniform series compound amount factor:

$$(F/A, i, N) = \frac{(1+i)^N - 1}{i}$$

- Capital recovery factor:

$$(A/P, i, N) = (A/F, i, N)(F/P, i, N) = \frac{i(1+i)^N}{(1+i)^N - 1}$$

- Series present worth factor:

$$(P/A, i, N) = (P/F, i, N)(F/A, i, N) = \frac{(1+i)^N - 1}{i(1+i)^N}$$

Discrete Compounding

Example 3: Calculating P from A, N and r

- What is the present value of a loan if it is fully paid off during 20 years by $500 monthly payments with an interest rate of 6%?
- Method 1:
  - r=0.06, m=12 and i_s = r/m → i_s= 0.005
  - N=20×12=240

$$(P/A, i, N) = \frac{(1+i)^N - 1}{i(1+i)^N}$$

$$\rightarrow P = 500 \times \frac{(1+0.005)^{240} - 1}{0.005 \times (1+0.005)^{240}}$$

$$\rightarrow P = 69790.4$$

Discrete Compounding

Example 3: Calculating P from A, N and r

- What is the present value of a loan if it is fully paid off during 20 years by $500 monthly payments with an interest rate of 6%?
- Method 2:
  - r=0.06, m=12 and i_s = r/m → i_s= 0.005
  - For one year (N=12):

$$(F/A, i, N) = \frac{(1+i)^N - 1}{i} \rightarrow F = 500 \times \frac{(1+0.005)^{12} - 1}{0.005} \rightarrow F = 6167.78$$

  - For 20 years (N=20 and i_e=$(1.005)^{12}$-1=0.0617):

$$(P/A, i, N) = \frac{(1+i)^N - 1}{i(1+i)^N} \rightarrow P = 6167.78 \times \frac{(1+0.0617)^{20} - 1}{0.0617 \times (1+0.0617)^{20}}$$

$$\rightarrow P = 69790.4$$

Discrete Compounding

Example 4: Calculating A from P, N and i

- How much will be the monthly payments to pay off a $25,000 loan in 5 years with a nominal interest rate of 12% compounded monthly?
  - r=0.12, m=12 and i_s = r/m → i_s= 0.01

$$(A/P, i, N) = \frac{i(1+i)^N}{(1+i)^N - 1}$$

$$\rightarrow A = 25000 \times \frac{0.01 \times (1+0.01)^{60}}{(1+0.01)^{60} - 1}$$

$$\rightarrow A = 25000 \times 0.0222 \rightarrow A = 556$$

Discrete Compounding

Example 5: Calculating A from P, N and i

- How much money should be set aside each year, for a period of 20 years, to accumulate $20,000, if the interest rate is 10%?

$$(A/F, i, N) = \frac{i}{(1+i)^N - 1}$$

$$\rightarrow A = 20000 \times \frac{0.1}{(1.1)^{20} - 1}$$

$$\rightarrow A = 350$$

Discrete Compounding

Example 6: Calculating N from P, A and i

- How long will it take to completely pay off a $1400 loan with $40 monthly payments if the interest rate is 1% per month?
  - i=0.01 and (P/A,1%,N) =1400÷40=35

$$(P/A, i, N) = \frac{(1+i)^N - 1}{i(1+i)^N}$$

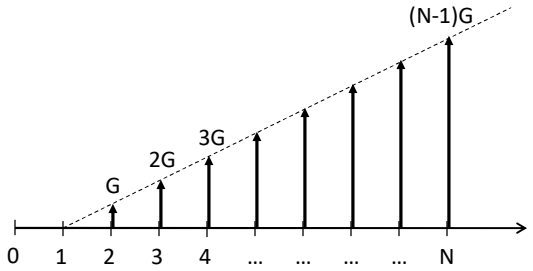
$$\rightarrow 35 = \frac{(1+0.01)^N - 1}{0.01 \times (1+0.01)^N} \rightarrow 35 = 100 - \frac{100}{(1.01)^N}$$

$$\rightarrow (1.01)^N = \frac{100}{65} \rightarrow N\ln(1.01) = \ln(1.538) \rightarrow N = 43.29$$

Discrete Compounding

Arithmetic Gradient Series

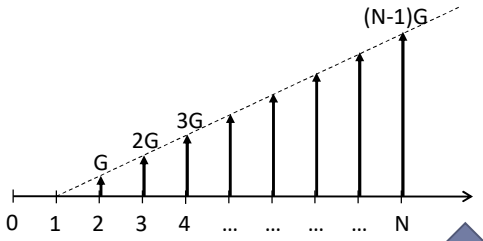
- A series of receipts or disbursements that starts at zero at the end of the first period and then increase by a constant amount from period to period.
- Important Note: The first non-zero cash flow occurs at the end of the second period.



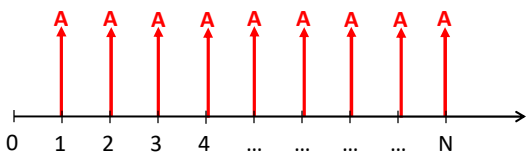
Discrete Compounding

Arithmetic Gradient Series

- Arithmetic gradient to annuity conversion factor:



$$(A/G, i, N) = \frac{1}{i} - \frac{N}{(1+i)^N - 1}$$



Discrete Compounding

Example 7: Calculating P from G, N and i

- An investment generates $100 value at the end of the second year increasing by $100 per year for the following 4 years. How much is the investment's worth today, at 15% interest?

$$P = G(A/G, i, N)(P/A, i, N)$$

$$P = G\left(\frac{1}{i} - \frac{N}{(1+i)^N - 1}\right)\left(\frac{(1+i)^N - 1}{i(1+i)^N}\right)$$

$$P = 100\left(\frac{1}{0.15} - \frac{6}{(1.15)^6 - 1}\right)\left(\frac{(1.15)^6 - 1}{0.15 \times (1.15)^6}\right)$$

$$P = 793.7$$

Discrete Compounding

Payback Period

- The time it takes for an investment to pay for itself, when the interest rate is assumed to be zero
- Example: What is the payback period for a $90,000 investment, if the investment yields a return of $25,000 per year?

$$\text{Payback period} = \frac{\text{First cost}}{\text{Annual savings}} = \frac{90000}{25000} = 3.6 \, years$$

Discrete Compounding

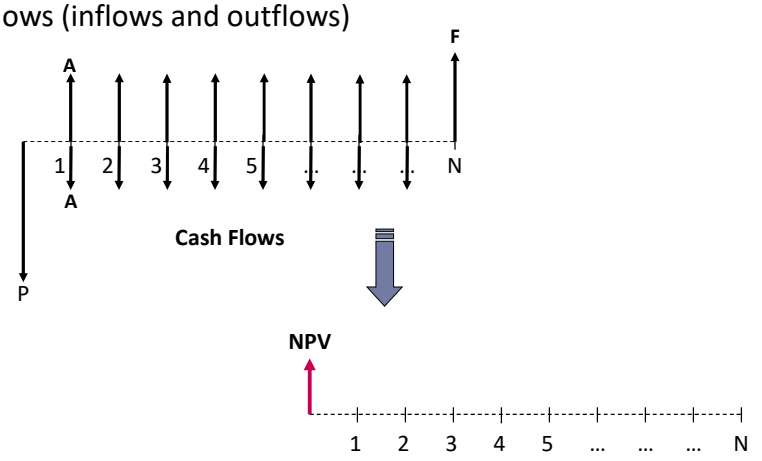
Minimum Attractive Rate of Return (MARR)

- The minimum rate of return at which the owner is willing to invest
- The interest rate used in feasibility studies
- Investments yielding less than the MARR are not desirable
- Also known as Minimum Acceptable Rate of Return

Discrete Compounding

Net Present Value (NPV)

- NPV is the sum of the Present Values (PVs) of all individual cash flows (inflows and outflows)



Discrete Compounding

Net Present Value (NPV)

- Cash inflow and outflow examples:

Inflows:

- Incremental revenues
- Cost reductions
- Release of working capital
- Salvage Value

Outflows:

- Initial investment
- Operating costs
- Working capital
- Maintenance

Discrete Compounding

Example 8: Calculating NPV

- Calculate the net present value of a project with an initial investment of $100,000, monthly benefit of $20,000 for 12 months, and the salvage value of $10,000. The target rate of return is 12% per annum.

$$NPV = -100000 + 20000(P/A,0.01,12) + 10000(P/F,0.01,12)$$

$$NPV = -100000 + (20000 \times \frac{(1+0.01)^{12}-1}{0.01 \times (1+0.01)^{12}}) + (10000 \times \frac{1}{(1+0.01)^{12}})$$

$$NPV = -100000 + 225102 + 8874$$

$$NPV = \$133{,}976$$

Discrete Compounding

Internal Rate of Return

- Rate of Return of a project is also known as Internal Rate of Return (IRR)
- "Internal" means the rate of return depends only on the cash flows due to the investment
- IRR is the interest rate at which a project just breaks even
- The internal rate of return on an investment is the interest rate, i*, at which the present worth of all cash inflows (receipts) equals the present worth of all cash outflows (disbursements)

Discrete Compounding

Example 9: Calculating IRR

- What is the IRR for a project that returns $690 after one year on a $600 investment?

$F = P (1+i^*)$

$\rightarrow 690 = 600 (1+i^*)$

$\rightarrow i = 15\%$

$\rightarrow$ IRR = 15%

Discrete Compounding

Internal Rate of Return

- To calculate the IRR, the disbursements should be set equal to the receipts. However, they should be comparable. Therefore:
  - PW (disbursements) = PW (receipts), or
  - AW (disbursements) = AW (receipts), or
  - FW (disbursements) = FW (receipts).
- Usually trial and error is required to calculate the IRR

Discrete Compounding

Example 10: Calculating IRR

- An investment costs $500, but returns $160 per year, up to 5 years. What is the IRR?
- Method 1: Using PW and interest formula:

$$500 = 160(P/A, i^*, 5)$$

$$\rightarrow 500 = 160\left(\frac{(1+i^*)^5 - 1}{i^*(1+i^*)^5}\right)$$

$$\text{Trial and error} \rightarrow i^* = 18.03\%$$

Discrete Compounding

Example 10: Calculating IRR

- An investment costs $500, but returns $160 per year, up to 5 years. What is the IRR?
- Method 2: Using AW and interest formula:

$$500(A/P,i^*,5) = 160$$

$$\rightarrow \left(\frac{i^*(1+i^*)^5}{(1+i^*)^5 - 1} \right) = 0.32$$

$$\text{Trial and error} \rightarrow i^* = 18.03\%$$

Discrete Compounding

Internal Rate of Return

- The IRR (i*) can be positive or negative
- A negative IRR means that project is loosing money rather than earning it.
- i* can be a negative value (feasible), but not less than -100%! Because if i* ≤ -100% then the entire amount is lost.
- $-100\% < i^* \leq \infty$

Discrete Compounding

IRR vs. MARR

- Projects with their IRR equal or exceeding their MARR are acceptable for investment.
- For comparing the IRR for two or more projects, their life period should be the same.

Discrete Compounding

Example 11: IRR Comparisons

- A new machine should be purchased at \$5,000 to return \$1,000/year for 10 years. The maintenance costs are \$200/year. If MARR= 10%, is buying the machine justifiable?

$$5000(A/P,i^*,10)+200=1000$$

$$\rightarrow (A/P,i^*,10)=0.16$$

$$\rightarrow \frac{i(1+i)^{10}}{(1+i)^{10}-1}=0.16$$

$$\text{Trial and error} \rightarrow i^*=9.6\% \rightarrow \text{IRR}=9.6\%$$

$$\text{IRR} < \text{MARR} \rightarrow \text{the new machine should not be purchased}$$

Discrete Compounding

Capitalized Cost

- The present worth of a project with an infinite life is called the capitalized or life cycle cost
- In other words, capitalized cost is the present worth of a project that lasts forever
- It is the amount of money required at time zero to perpetually support the project on the earned interest only
- Applications are in government projects such as roads, dams and bridges (projects that possess perpetual life)

Discrete Compounding

Capitalized Cost

- Derivation:

$$\text{Capitalized Cost (CC)} = P$$

$$P = \lim_{N\to\infty} A(P/A, i, N)$$

$$= \lim_{N\to\infty} A\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right]$$

$$= \lim_{N\to\infty} A\left[\frac{1 - \frac{1}{(1+i)^N}}{i}\right]$$

$$= \frac{A}{i}$$

Discrete Compounding

Example 12: Calculating Capitalized Cost

- Example: What is the capitalized cost to maintain a facility forever, if the maintenance cost is $2,500 per year and the interest rate is 5%?
- Answer: CC = A/i = 2500÷0.05 = $50,000

Exercise

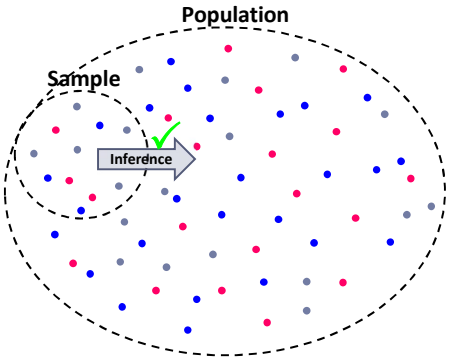
Questions 78 to 89: Engineering Economics

Section 7: Statistics, Probability, and Risk

Statistics

Statistics

- Descriptive: summarization and description of data
- Inferential: estimation, predictions, or generalization about the population based on the data from a sample:
  - Population
  - Sample
  - Statistical inference
  - Reliability



Statistics

Mean

- Sum of the measurements divided by the number of measurements
- Example Mean = 448 ÷ 16 = 28

No.	Value
1	21
2	21
3	22
4	22
5	22
6	22
7	26
8	28
9	29
10	30
11	30
12	32
13	33
14	33
15	38
16	39
Total	**448**

Statistics

Median

- The middle number when the data are sorted ascending (or descending)
  - If the number of measurement are odd, the median is the middle number
  - If the number of measurements are even, the median is the average of the two middle measurements
- Example Median= (28 + 29) ÷ 2 = 28.5

No.	Value
1	21
2	21
3	22
4	22
5	22
6	22
7	26
8	28
9	29
10	30
11	30
12	32
13	33
14	33
15	38
16	39
Total	**448**

Statistics

Mode

- The measurement that occurs most often
- There may be no mode or several modes
- Example Mode = 22

No.	Value
1	21
2	21
3	22
4	22
5	22
6	22
7	26
8	28
9	29
10	30
11	30
12	32
13	33
14	33
15	38
16	39
Total	**448**

Statistics

Range

- The difference between the largest and the smallest values in the data set
- Example Range = 39 – 21 = 18

No.	Value
1	21
2	21
3	22
4	22
5	22
6	22
7	26
8	28
9	29
10	30
11	30
12	32
13	33
14	33
15	38
16	39
Total	**448**

Statistics

Variance

- The average of the squared deviations from the mean
- Population Variance:

$$\sigma^2 = \frac{\sum(x-\mu)^2}{N} = \frac{\sum x^2 - N\mu^2}{N}$$

- Sample Variance:

$$s^2 = \frac{\sum(x-\bar{x})^2}{n-1} = \frac{\sum x^2 - n\bar{x}^2}{n-1}$$

No.	Value
1	21
2	21
3	22
4	22
5	22
6	22
7	26
8	28
9	29
10	30
11	30
12	32
13	33
14	33
15	38
16	39
Total	**448**

Statistics

Variance

- Example:
  - As a Population Variance:

$$\sigma^2 = \frac{\sum(x-\mu)^2}{N} = \frac{542}{16} = 33.9$$

  - As a Sample Variance:

$$s^2 = \frac{\sum(x-\bar{x})^2}{n-1} == \frac{542}{15} = 36.1$$

No.	Value	$(x-\mu)^2$
1	21	49
2	21	49
3	22	36
4	22	36
5	22	36
6	22	36
7	26	4
8	28	0
9	29	1
10	30	4
11	30	4
12	32	16
13	33	25
14	33	25
15	38	100
16	39	121
Total	**448**	**542**

Statistics

Standard Deviation

- The square root of the variance
- Population Variance:

$$\sigma = \sqrt{\frac{\sum (x-\mu)^2}{N}} = \sqrt{\frac{\sum x^2 - N\mu^2}{N}}$$

- Sample Variance:

$$s = \sqrt{\frac{\sum (x-\bar{x})^2}{n-1}} = \sqrt{\frac{\sum x^2 - n\bar{x}^2}{n-1}}$$

- Has the same units as the original data
- Most commonly used measure of variation

No.	Value	$(x-\mu)^2$
1	21	49
2	21	49
3	22	36
4	22	36
5	22	36
6	22	36
7	26	4
8	28	0
9	29	1
10	30	4
11	30	4
12	32	16
13	33	25
14	33	25
15	38	100
16	39	121
Total	**448**	**542**

Statistics

Standard Deviation

- Example:
  - As a Population Standard Deviation:

$$\sigma = \sqrt{\frac{\sum (x-\mu)^2}{N}} = \sqrt{\frac{542}{16}} = 5.8$$

  - As a Sample Standard Deviation:

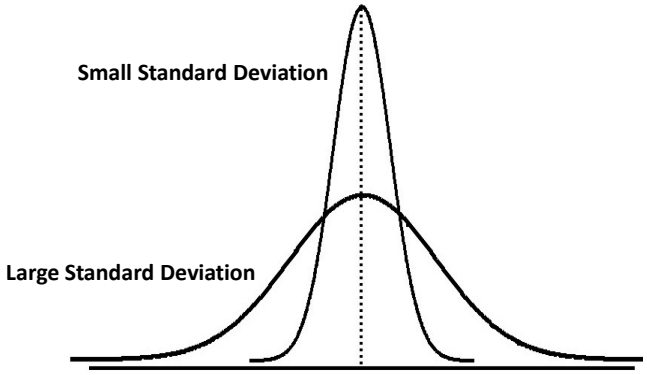
$$s = \sqrt{\frac{\sum (x-\bar{x})^2}{n-1}} = \sqrt{\frac{542}{15}} = 6$$

No.	Value	$(x-\mu)^2$
1	21	49
2	21	49
3	22	36
4	22	36
5	22	36
6	22	36
7	26	4
8	28	0
9	29	1
10	30	4
11	30	4
12	32	16
13	33	25
14	33	25
15	38	100
16	39	121
Total	**448**	**542**

Statistics

Standard Deviation

- Comparison



Statistics

Percentile

- A percentile indicates how the data are spread over the data set
- The *p*th percentile is the value with exactly *p* percent of the measurements fall below it.
- Example:
  - 12th percentile = 21
  - 75th percentile = 32

	No.	Value
P12	1	21
	2	21
	3	22
	4	22
	5	22
	6	22
	7	26
	8	28
	9	29
	10	30
P75	11	30
	12	32
	13	33
	14	33
	15	38
	16	39
	Total	**448**

Statistics

Quartile

- Quartiles are specific percentiles:
  - First quartile = 25th percentile = 22
  - Second quartile = 50th percentile = 28
  - Third quartile = 75th percentile = 32
- Inter-quartile range: The middle 50 percent of the values
  - Example: 32-22 = 10
- Quartile Deviation: The inter-quartile range divided by 2
  - Example: QD = 10÷2 = 5

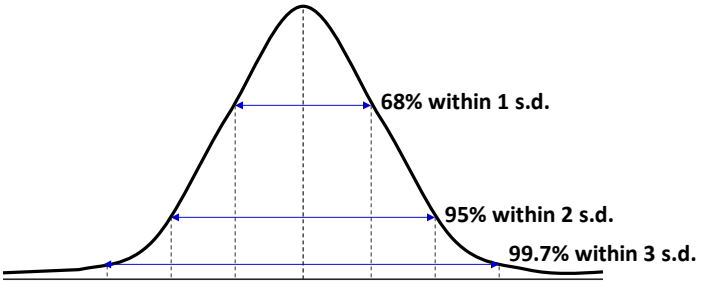
	No.	Value
	1	21
	2	21
P25	3	22
	4	22
	5	22
	6	22
P50	7	26
	8	28
	9	29
	10	30
P75	11	30
	12	32
	13	33
	14	33
	15	38
	16	39
	Total	**448**

Inter-quartile range = 10

Statistics

Normal Distribution (Curve)

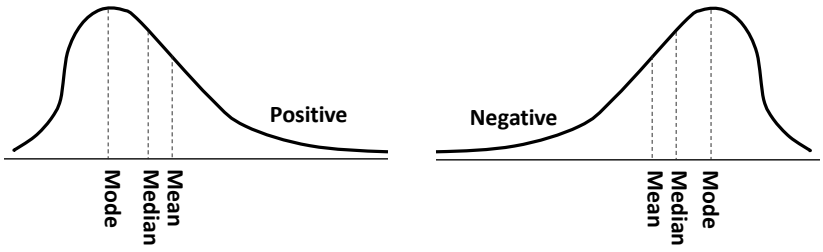
- The Normal Curve is a unimodal curve with mean, median and mode at the same point
- It is symmetrical with the maximum height at the mean
- Most frequencies occur within +/- 3 standard deviations



Statistics

Skewed Distribution

- If a distribution is skewed and not symmetrical (scores are concentrated more at one end or the other), then three measures of central tendency will not be equal. The median lies between the mode and mean in all skewed distributions.



Statistics

Final Notes

- Mean, mode and median are measures of “central tendency”
- Range, inter-quartile range, variance, standard deviation and quartile deviation are measures of “variability”

Exercise

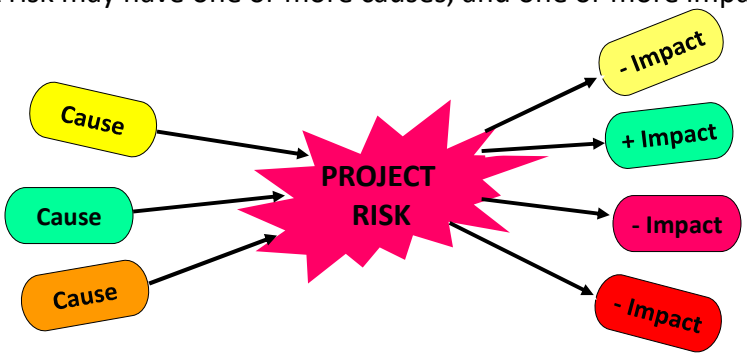
Questions 90 to 96: Statistics

Risk Management

Risk Management

Project Risks

- Project risk is any issue that may occur and prevent achieving project objectives
- Positive risks = opportunities
- A risk may have one or more causes, and one or more impacts



Risk Management

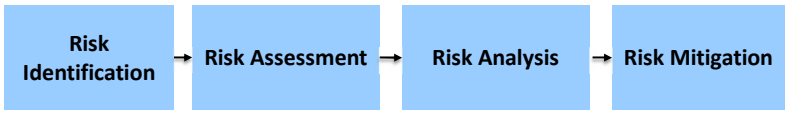
Types of Project Risks

- External (strategic): Project team or company cannot control
  - Example: Force majeure, labor strikes, changes in tax regimes
- Internal (tactical): Project team or company can control
  - Example: Design errors and omissions, selecting poor subcontractor

Risk Management

Risk Management Approach

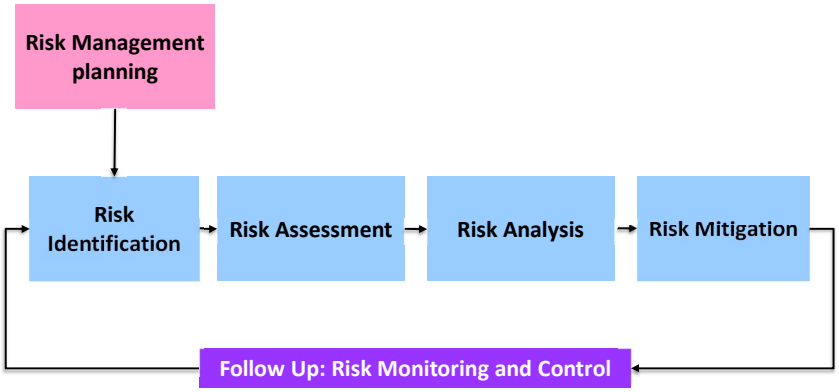
- The fundamental risk management approach:
  - Identification
  - Assessment
  - Analysis
  - Mitigation



Risk Management

Risk Management Steps

- A continuous process throughout the project lifecycle



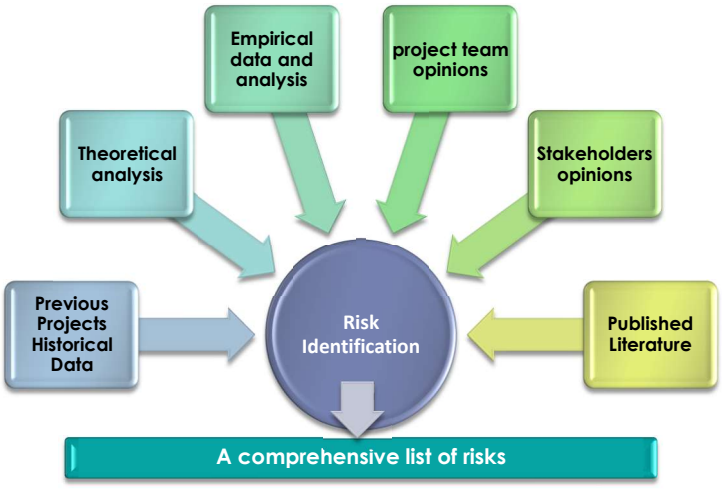
Risk Management

Risk Management Planning

- Generate Risk Management Plan
  - Part of project execution plan
  - Explains the risk management methodology and requirements
  - Risk management activities
  - Defines roles and responsibilities for managing risks
  - Highlights qualitative vs. quantitative risk assessment requirements
  - Identifies risk management codes and standards

Risk Management

Risk Identification



Risk Management

Risk Register

- Example:

Risk	Prob.	Impact				Score	Response
		Cost	Time	Quality	Safety		
Lack of skilled labors on site							
Late delivery of major equipment							
Cold weather in Winter							
…							

Risk Management

Risk Assessment

- Allocating probability and impact values to identified risks
- Risk impact areas:
  - Cost
  - Schedule
  - Quality
  - Safety
  - Etc.
- Example:

Values	Probability
Hi	More than 75%
Med	Between 25% to75%
Lo	Less than 25%

Values	Impact on Cost	Impact on Schedule
Hi	More than 1% of project cost	More than 2 weeks
Med	Between 0.1% to1% of project cost	Between 1 week and 2 weeks
Lo	Less than 0.1% of project cost	Less than 1 week

Risk Management

Risk Register

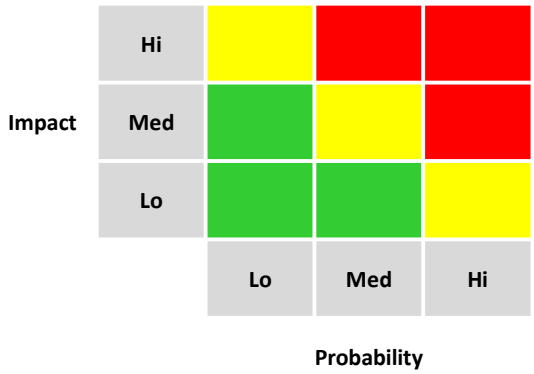
- Example:

Risk	Prob.	Impact				Score	Response
		Cost	Time	Quality	Safety		
Lack of skilled labors on site	Med	Lo	Hi	Med	Lo	Med	
Late delivery of major equipment	Lo	Lo	Hi	Lo	-	Lo	
Cold weather in Winter	Hi	Hi	Hi	Med	Med	Hi	
…							

Risk Management

Risk Analysis

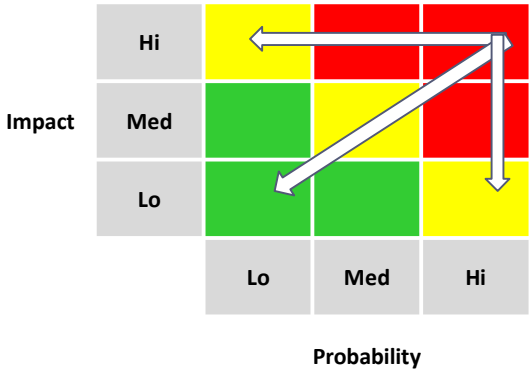
- Review and refine
- Risk ranking and prioritization



Risk Management

Risk Mitigation (Response)

- According to "Skills and Knowledge of Cost Engineering, 5th Edition", below are risk mitigation methods:
  - Avoidance
  - Prevention
  - Reduction
  - Transfer
  - Hedging
  - Insurance



Risk Management

Risk Response

- Eliminate risk: Avoid the risk completely
- Mitigate risk: Reduce probability and/or impact
- Deflect risk: Transfer the risk to another party (through contracts, financial agreements, insurance policies, etc.)
- Accept risk: Accept the risk with contingency
- Combination of the above

Risk Management

Risk Register

- Example:

Risk	Prob.	Impact				Score	Response
		Cost	Time	Quality	Safety		
Lack of skilled labors on site	Med	Lo	Hi	Med	Lo	Med	1. Pay competitive wages 2. Use labors from overseas
Late delivery of major equipment	Lo	Lo	Hi	Lo	-	Lo	1. Utilize robust expediting methods 2. Order long lead items sooner
Cold weather in Winter	Hi	Hi	Hi	Med	Med	Hi	Close the site during Jan. to Feb.
…							

Risk Management

Follow-Up

- Risks are inherent in all projects, no project is risk free
- New risks may present themselves at any time despite the best planning efforts
- Risks management should be a continuous effort throughout the project life cycle
- Risk management needs regular monitoring, updating, and communicating

Risk Management

Risk Register

- Example:

Risk	Prob.	Impact				Score	Response
		Cost	Time	Quality	Safety		
Lack of skilled labors on site	Med	Lo	Hi	Med	Lo	Med	1. Pay competitive wages 2. Use labors from overseas
Late delivery of major equipment	Lo	Lo	Hi	Lo	-	Lo	1. Utilize robust expediting methods 2. Order long lead items sooner
Cold weather in Winter	Hi	Hi	Hi	Med	Med	Hi	Close the site during Jan. to Feb.
…							

Risk Management

Definitions

- **Risk Register:** A list of identified risks and their assessment, analysis , and response actions
- **Risk Trigger:** Symptom or warning sign indicating that a risk event has occurred or is about to occur
- **Residual Risk:** The risk that remains after a risk response has been taken
- **Secondary Risk:** A risk that arises as the result of implementing a risk response
- **Issue:** A risk that has happened

Risk Management

Quantitative Risk Analysis

- The use of mathematical techniques and models to numerically establish the probability and impact of risk
  - Simulation (Monte Carlo)
  - Sensitivity Analysis (what-if analysis)
  - Decision Trees

Exercise

Questions 97 to 100: Risk Management

Section 8: Technical Paper Writing

Technical Paper Writing

Important Note to Start With

- The Certification Board recommends your technical paper topic be something with which you are already familiar, such as a project you have done at work or something in which you have acquired a great deal of expertise in your professional career. The chosen topic is not as important as your ability to communicate through your paper.

Technical Paper Writing

Planning

- Decide the idea or subject
- Decide the audience (paper level)
- Decide the start and finish (the scope)
- Decide the preliminary title for the paper
- Categorize and organize the subtitles and generate the high level outline

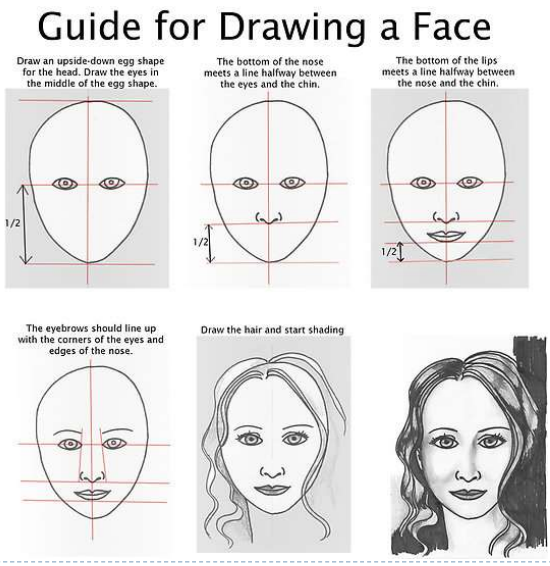
Technical Paper Writing

Drafting

- Study and read some related references
- Under each subtitle, briefly note the important points and subjects (bullet wise)
- Convert the important points to text and paragraphs
- Note the following:
  - Avoid informal writing, write formally
  - Ensure the correct flow of information
  - Do not miss important sections
  - Avoid unnecessary repeating
  - Keep it simple; stay close to the min. 2500 words, never exceed 5000
  - Use diagrams and figures more often to support the text
  - Cite references and follow a well known referencing method (e.g. APA)
  - Avoid copyright infringement

Technical Paper Writing

Drafting



Technical Paper Writing

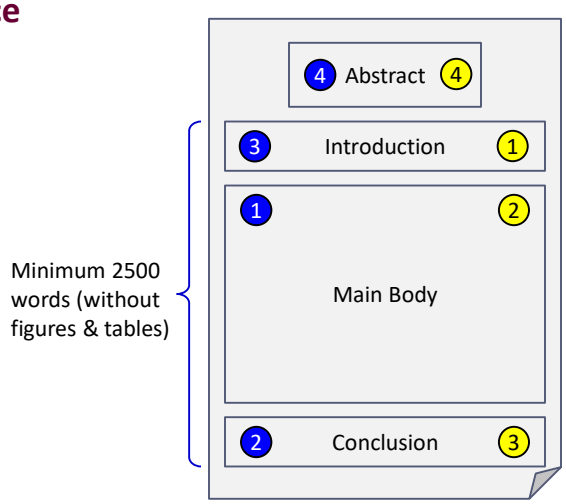
Review

- Read and modify the paper a few times
- Redefine the paper title, if necessary
- Ask an editor or a technical writer to review and make corrections
- After editing, ask a few colleagues to read the paper and comment
- Incorporate valid comments

Technical Paper Writing

Writing Sequence

1. Main body
2. Conclusion
3. Introduction
4. Abstract



Technical Paper Writing

Abstract, Introduction, and Conclusion Contents

- Abstract
  - Background and objective
  - Who is the audience, who benefits from the paper
  - How the paper is structured
  - Major achievements or highlights
- Introduction
  - Background and objective
  - How the paper is written, where the knowledge comes from
  - Who is the audience, who benefits from reading the paper
  - How the paper is structured: sections and sub-sections
- Conclusion
  - Major achievements or highlights
  - Future research or related topics for further reading

Feedback

Please let us know how we did!

References

- AACE International CCP Certification Study Guide, 2nd Edition
- AACE's Skills & Knowledge of Cost Engineering, 6th Edition
- AACE's Total Cost Management Framework
- Project Management Body of Knowledge (PMBOK), 6th Edition
- Global Engineering Economics, 4th ed.