Construction Project Management
(CE 110401346)

1 – Introduction to Construction

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Construction

- Construction is the process that sets up a portable plant, bring material to the site, and on completion of the work moves the plant away, leaving its output standing
- Output: all immobile structures (airports, buildings, dams, roads and tunnels, power plants, municipal treatment plants, pipelines …etc)

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Project

- Project: A temporary effort undertaken to create a unique product or service.
- "Any undertaking with a defined *STARTING* and *ENDING* point and defined *OBJECTIVES* by which completion is identified. In practice, most projects depend on limited *RESOURCES* by which the objectives of the project are accomplished."
- Project Management Institute

Characteristics of the Construction Industry

- The physical nature of the product:
  - Large, heavy and expensive
  - Required over a wide geographical area
  - Customer tailored
  - A large part of components manufactured elsewhere
- The ultimate use of the product is:
  - As a mean to further production
  - As an addition to or improvement of the infrastructure of the economy (e.g., roads)
  - As a social investment (e.g., hospitals)
  - As an investment for direct enjoyment (e.g., housing)

Characteristics of the Construction Industry II

- The demand for the product is:
  - Determined differently for different types of products
  - Largely dependent on governmental policy
  - Largely dependent on economy cycles
- Unique Industry:
  - Incorporates small remodeling to giant international, multibillion-dollar contractors.
  - Highly competitive.
  - Low profit margins.

Characteristics of the Construction Industry III

- Many parties are involved in the process:
  - Owner
  - Architect
  - Contractor
  - Subcontractors
  - Materials and equipment suppliers
  - Regulatory agencies
  - etc….
- The price determination is a discrete process for each project and for each piece of work subcontracted (bidding or negotiations)

Characteristics of the Construction Industry IV

- Human resources: Growing shortage of skilled workers due to:
  - 4D Industry Perception (dull, dirty, demanding, and dangerous)
  - Aging workforce
  - Absence of apparent technology
  - Requirement to travel

Characteristics of the Construction Industry V

- Safety:
  - Construction accounted for 19.5% of all workplace fatalities in 2000 in the United States (about 5% of the total U.S. workforce)
- Quality control:
  - In this competitive age, if you do not provide quality services, someone else will

Construction Projects Categories I

- Industrial, heavy engineering and infrastructure, commercial buildings, residential
- Industrial
  - Examples: automobile plants, petroleum refineries, petrochemical plants, steel mills, nuclear plants …etc)
  - Dominated by very large engineering and construction firms
  - The most technical projects of the construction projects
  - Few design firms and constructors are qualified to undertake them
  - Privately funded

Construction Projects Categories II

- Heavy Engineering and infrastructure
  - Examples (airports, bridges, dams, tunnels, highways, water treatment and distribution, urban rapid transit systems …etc)
  - Activities in this category are primarily the domain of civil engineers, but other engineering disciplines have roles
  - Equipment intensive and characterized by fleets of large earth movers, heavy trucks, etc)
  - Working with massive quantities of basic materials (earth, rock, concrete, steel, pipe)
  - Many of those projects are publicly funded
  - Projects tend to be long in duration

Construction Projects Categories III

- Commercial Building
  - Examples (Mosques, churches, government buildings, hospitals, shopping malls, small retail stores, warehouses…etc)
  - Labor and materials intensive
  - Interact closely with people
  - Private economy finances these structures, with some exceptions
  - Design coordinated by architects, who work with engineering specialists (structural, mechanical, electrical)

Construction Projects Categories IV

- Residential
  - Examples (single-family homes, apartments, condominiums, town houses)
  - Largely financed by private investment
  - Large number of contractors and subcontractors
  - High rate of business failure if demand falls
  - Low capital and labor intensive
  - Design is done by architects, drafting people, builders, or the home owner (USA)

Construction Projects Categories V

- In terms of owner, construction projects are either Public or Private Projects.
  - A private party can award a contract in any way they choose to anyone they choose.
  - Private party can make one contract or multiple
  - Public party is limited by laws and regulations
  - Public party commonly awards bids by competitive bidding.

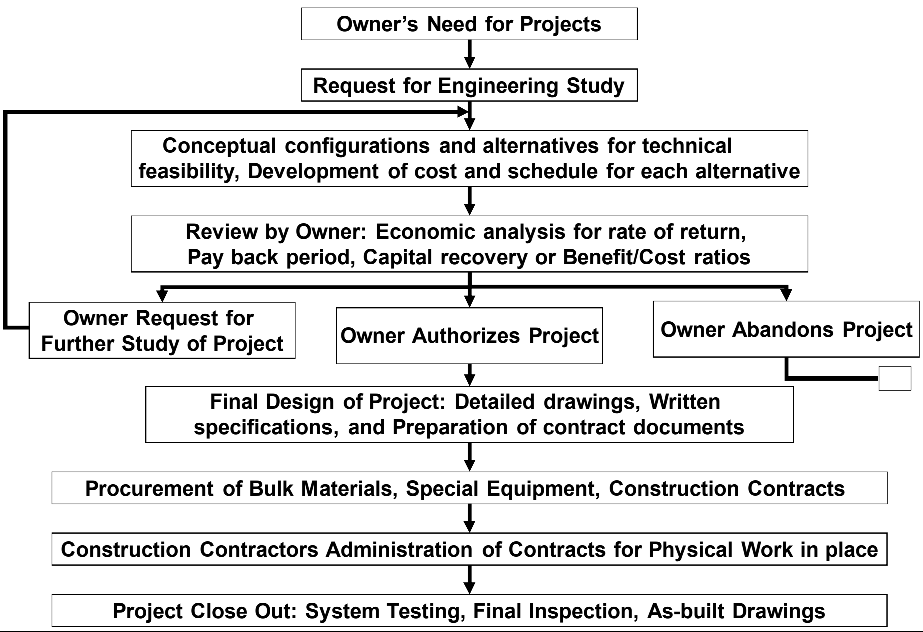
Construction Contractors

- Construction contractors: Companies and individuals engaged in the business of construction
  - They operate under a contract arrangement with the owner
- Construction contractors
  - General contractors: engage in a wide range of construction activities and execute most major construction projects
  - Specialty contractors: limit their activities to one or more construction specialties

Phases of a Project

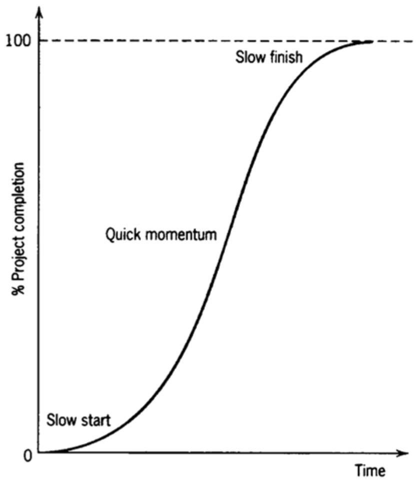
- Business Planning
- Conceptual Design
- Detailed Design
- Procurement
- Construction
- Testing, Start-up & Implementation
- Operations & Utilization
- Decommissioning

Phases of a Project II



The Project Life Cycle

- Slow-rapid-slow progress
- Minimal effort is required at the beginning but increasing effort in the early stages of the life cycle will improve the chances of project success

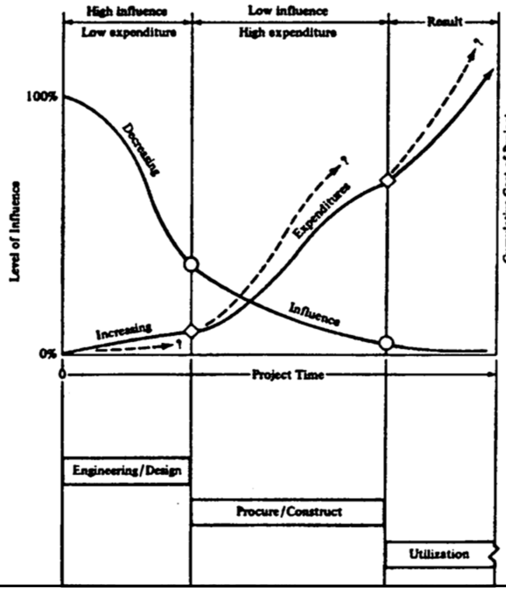


Phases of a Project III

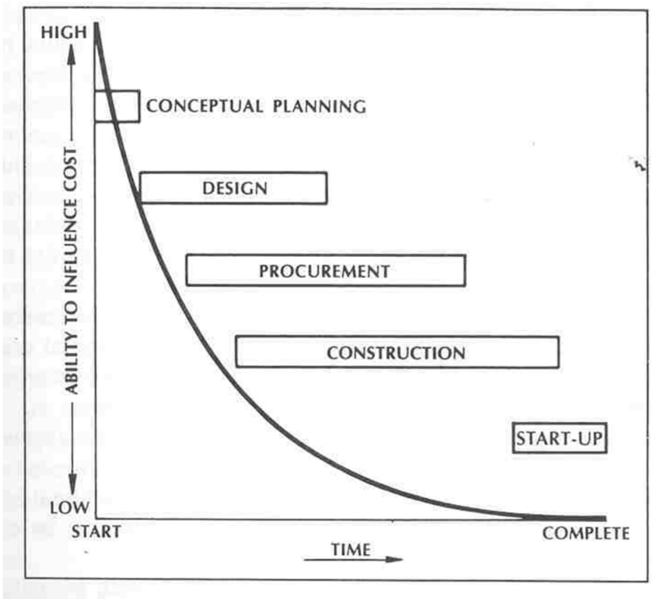
- The cost of each phase depends on specifics, but usually the majority of the budget is spent during the production phase
- Most of the budget is committed during the design phase before the actual work takes place
- Pressures to start the “real-work” may lead to high cost due to commitment of resources without adequate planning

The Level of Influence Concept

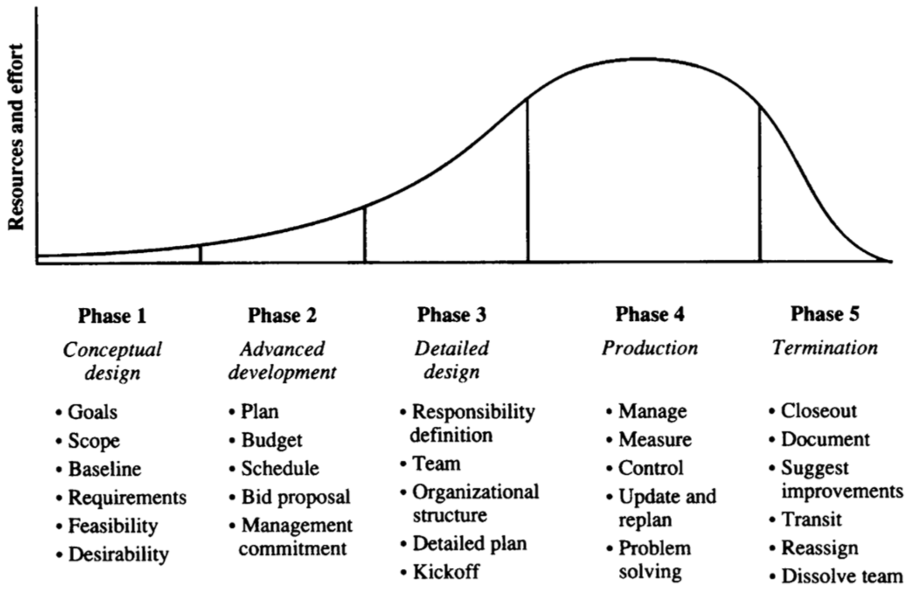
Level of influence on project costs. (From Boyd C. Paulson, Jr., "Designing to Reduce Construction Costs," *Journal of the Construction Division*, ASCE, vol. 102, no. CO4, December 1976, p. 588.)



The Level of Influence Concept



Life Cycle Strategic and Tactical Issues



Project Management

- "The art of *DIRECTING* and *COORDINATING* human and material *RESOURCES* throughout the life of a project by using modern management techniques to achieve *PREDETERMINED OBJECTIVES* of scope, quality, time, and cost, and participants' satisfaction."

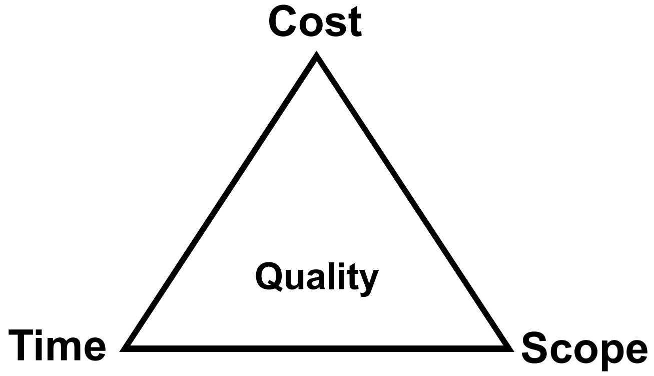
Project Management Institute

Construction Management

- Construction Management: the act of managing the construction process
- The construction manager manages the basic resources of construction
  - Workers and subcontractors
  - Equipment and construction plant
  - Materials
  - Money (income, expenditure, and cash flows)
  - Time

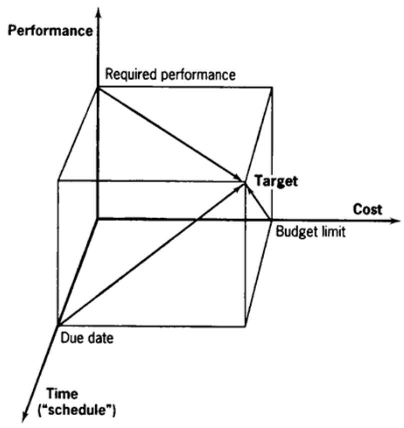
Construction Management II

Construction Management Triangle



Construction Management III

Managing Trade-Offs: The Primary Task of Construction Management



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2. Construction Planning

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Project Planning I

- *Well begun is half done*
- Planning can be thought of as determining "what" is going to be done, "how," "where," and by "whom"
- We all do planning and scheduling on a regular, informal, basis
  - Often it is necessary to create a "to-do list"
- As the number of items increases and/or time frame expands, we put our list in the context of time

Project Planning II

- Owners want their projects completed within specified time and budget constraints
- Planning and scheduling is done extensively and formally on construction projects
  - Beginning with the Notice of Award

Project Time Management

- Project Time Management: It includes the processes required to ensure timely completion of the project.
- It includes:
  - Activity definition
  - Activity sequencing
  - Activity resource Estimating
  - Activity duration Estimating
  - Schedule development
  - Schedule control

Project Time Management II

- **Activity Definition**: Identifying the specific schedule activities that need to be performed to produce the various project deliverables
- **Activity Sequencing**: Identifying and documenting dependencies among schedule activities
- **Activity Resource Estimating**: Estimating the type and quantities of resources required to perform each schedule activity
- **Activity Duration Estimating**: Estimating the number of work periods that will be needed to complete individual schedule activities

Project Time Management III

- **Schedule Development**: Analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule
- **Schedule Control**: Controlling changes to the project schedule

Planning and Scheduling What?

- What is Planning and Scheduling?
  - **Planning & Scheduling:** provides a project plan/schedule that is essential in project time management.
- **Project Time Management:**
  - **Planning.**
  - **Scheduling.**
  - **Tracking and Control.**

Planning and Scheduling Why?

- Why do we Plan and Schedule?
- Planning & Scheduling is needed for:
  - Scope recognition.
  - Task definition & responsibility identification.
  - Effective utilization of resources (labor, material & equipment).
  - Tracking and controlling project time and cost.
  - Contractual requirement
  - Claims analysis, quantification and defense.

Planning and Scheduling How?

- **How do we Plan and Schedule?**
  - **Planning Determines:**
    - What must be done?
    - How it is to be performed?
    - What sequential order it will follow?
- **Planning Requires:**
  - Ability to visualize discrete work elements.
  - Establishing interdependencies.
  - Intimate knowledge of construction methods.

Planning and Scheduling How?

- **Planning Steps:**
  - Generate Work Breakdown Structure (WBS) & Activity List.
  - Estimate Activity Duration/Cost.
  - Determine job logic (sequential relationships among activities).
  - Draw graphic presentation in a network.

Defining Activities I

- **The schedule consists of tasks that must be performed—to complete the project**
- **The schedule is dominated by verbs—things to do—tasks**

Defining Activities II

- **Activity: a single work task that consumes time and has a recognizable start and finish times.**
- **Activity: A component of work performed during the course of a project** (PMBOK)
- **Schedule Activity:** A discrete scheduled component of work performed during the course of a project. A schedule activity normally has an estimated duration, an estimated cost, and estimated resource requirements. Schedule activities are connected to other schedule activities with logical relationships, and are decomposed from work packages.

Defining Activities III

- **Guidelines for Identifying Activities:**
  - Area of responsibility (general contractor, subcontractor).
  - Location on site.
  - Structural element (substructure, superstructure, etc.)
  - Craft or crew requirements.
  - Equipment requirements.
  - Material utilized (concrete, timber, steel, etc.)

Defining Activities IV

- **Factors Affecting Level of Detail (Number of Activities):**
  - Nature and size of project.
  - Required level of detail.
  - Which level of management will use the schedule.

Generating Work Breakdown Structure I

- Most projects for which formal schedules are used are defined with hundreds or thousands of activities
- It is important that the logic be carefully laid out and that all important tasks are included in the schedule
- When the tasks become numerous, the schedule development can becomes more haphazard,
  - Omissions are sure to occur

Generating Work Breakdown Structure II

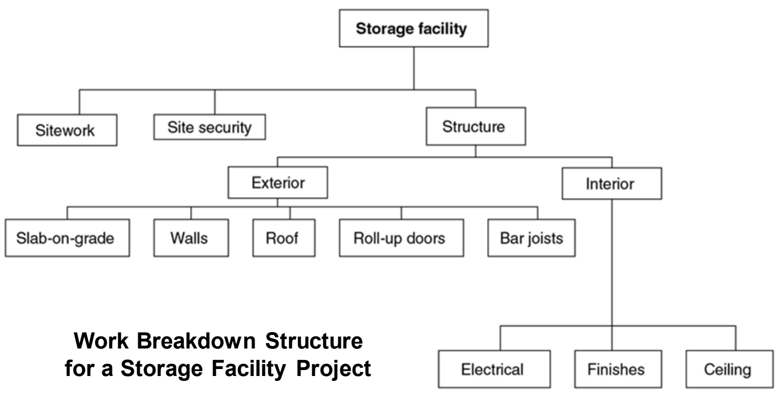
- A *Work Breakdown Structure* (WBS) is a systematic way to describe components of a project
- Developing the WBS begins with the definition of the major systems or components of a project
- Each system is defined in greater and greater detail until there exists a discrete or measurable piece of work and a single responsibility—work packages
- Work packages can be viewed as mini projects that are contained within the entire project

Generating Work Breakdown Structure III

- **Work breakdown structure (WBS):** Describes the project scope of work in a hierarchy of work packages, where each abstract work package in the higher levels of the hierarchy is subdivided into more detailed work packages in lower levels of the hierarchy.
- The WBS is an orderly presentation of the tasks that must be performed to complete a particular project

Generating Work Breakdown Structure IV

- On a typical construction project the WBS consists of numerous categories—depending on complexity



Work Breakdown Structure for a Storage Facility Project

Generating Work Breakdown Structure V

- **Uses of WBS:**
  - Identifying scope of work.
  - Preparing preliminary budget.
  - Cost estimating.
  - Scheduling.
  - Identifying cost & schedule at various levels of details.
  - The backbone of the project control or tracking system (Time & cost control).
  - Identifying individual or departmental responsibilities.

Activities Coding System I

- **Types of Coding Systems:**
  - Standard code
  - Project code
- **Standard Code**: is a systematic classification & categorization of all items of work or cost pertaining to a specific type of construction (e.g. Building construction, Heavy construction).

Activities Coding System II

- **Purpose of Standard Code:**
  - Provides a comprehensive checklist of all items of work that can be found in a specific type of construction.
  - Provides for uniformity, transfer & comparison of information among projects.
- **Example**: **Masterformat** was developed through a joint effort of 8 industry & professional associations including:
  - **Construction Specifications Institute (CSI)**
  - **Construction Specifications Canada (CSC)**

Activities Coding System

- **Divisions:**

1. **General Requirements.**
2. **Site work.**
3. **Concrete.**
4. **Masonry.**
5. **Metals.**
6. **Woods & Plastics.**
7. **Thermal & Moisture Protection.**
8. **Doors & Windows.**
9. **Finishes.**
10. **Specialties.**
11. **Equipment**
12. **Furnishings.**
13. **Special Construction.**
14. **Conveying Systems.**
15. **Mechanical.**
16. **Electrical.**

Activities Coding System

- **Project Code**: is a systematic classification & categorization of all items of work or cost pertaining to a specific project.

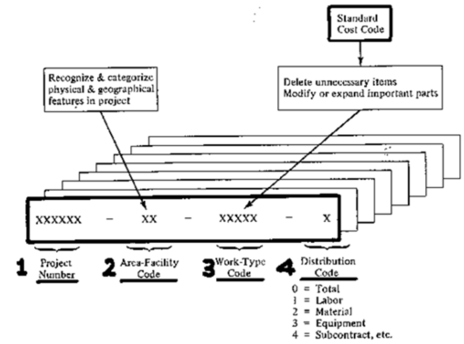


FIGURE 13-3
Developing project code from standard code.

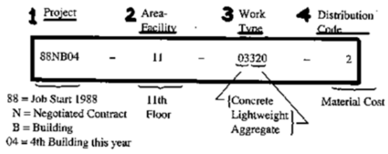


FIGURE 13-4
Example project code.

Determining Job Logic I

- For each identified activity, the following must be determined:
  - *Which activities must precede it?*
  - *Which activities must follow it?*
  - *Which activities can be concurrent with it?*
- Constraints exist in the real world—and must be considered in order for a network to be useful

Determining Job Logic II

- **Construction Planning Constraints:**
  - Physical Constraints **:** (formwork must precede pouring concrete).
  - Resource Constraints **:**
    - Availability of material.
    - Availability of equipment.
    - Availability of labor.
    - Availability of money.
  - Safety Constraints.
  - Environmental Constraints
    - Weather.
    - Economical.
    - Social.
    - Political.

Determining Job Logic II

- Introduction of excessive constraints in network logic can have the following impacts on a project:
  - Reduce scheduling flexibility
  - Lengthen project duration
  - Generally increase project cost
  - Confuse basic scheduling logic

The Hashemite University

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3. Construction Scheduling

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Planning and Scheduling I

- There is a significant difference between "*planning*" and "*scheduling*"
  - The planning portion of a construction project relates to developing the logic of how a project will be constructed
  - Scheduling consists of integrating that plan with a calendar or specific time frame
  - Scheduling consists of determining the time needed for each of the planned tasks and the overall length of the project schedule
- Scheduling can never be performed effectively without planning

Project Scheduling: What?

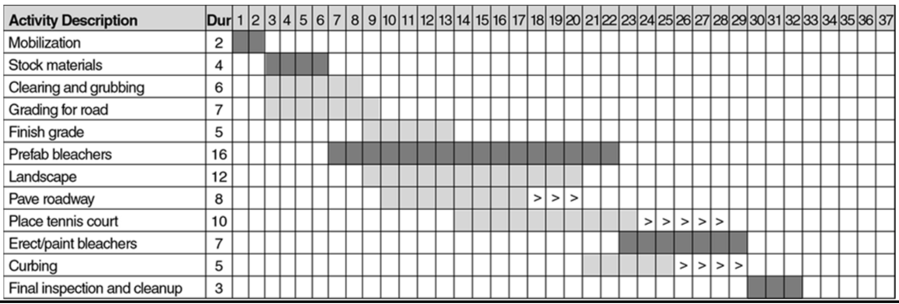
- What is Project Scheduling?
  - **Scheduling:** Planning + Time
  - Project Schedule: the planned dates for performing schedule activities and the planned dates for meeting schedule milestones
- **It Establishes:**
  - Project duration & finish time.
  - Activity start & finish times.
  - Activity floats.
  - Critical activities.
  - Used in resource scheduling.

Scheduling Tools

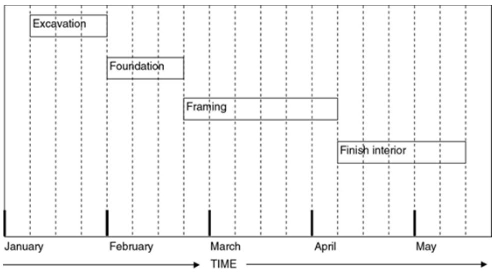
- **Scheduling Tools:**
  - Bar Chart.
  - Critical Path Method (CPM).
  - Precedence Diagram Method (PDM).
  - Program Evaluation & Review Technique (PERT).
  - Line of Balance (LOB).

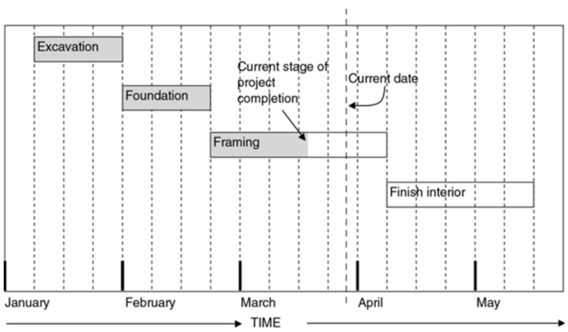
Bar Charts I

- Developed early in the 1900s (Henry Gantt)
- Advantages:
  - Easily read and understood.
  - Effective communication between engineer & foreman.
  - Useful in identifying required resources.



Bar Charts II





Bar Charts III

- **Disadvantages:**
  - They do not show clear dependencies between activities (job logic)
  - Ineffective in determining the impact of delaying one activity on project finish time.
  - Cumbersome & difficult to comprehend logic when the number of activities increase (when projects become more complex).

Network Scheduling Techniques I

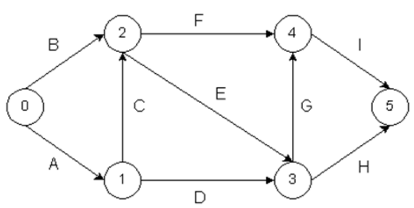
- Network Techniques: were developed in the late 1950s.
- A network represents a model, or plan, of the project as it is proposed to be undertaken
- Each activity is assigned duration; calculations through the network provide a single, specific duration for the project as a whole
- It is important to recognize the distinction between *duration* and *event*

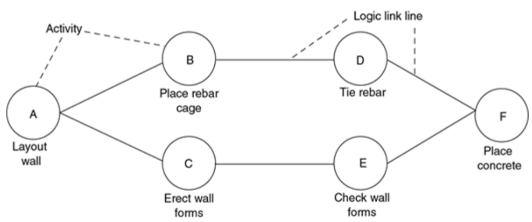
Network Scheduling Techniques II

- An event is the point in time, or an instant at which the status of completion of a project or activity can be defined
- The duration of an activity is the time that will be consumed in completing a task
- **Types of Network Scheduling:**
  - Activity on Arrow (AOA) or Critical Path Method (CPM)
  - Activity on Node (AON) or Precedence Diagram Method (PDM).

Network Scheduling Techniques III

- Activity on Arrow (AOA): Activities are represented as arrows or lines
  - Activity on Node (AON): Activities are represented as nodes





Activity on Arrow (CPM)

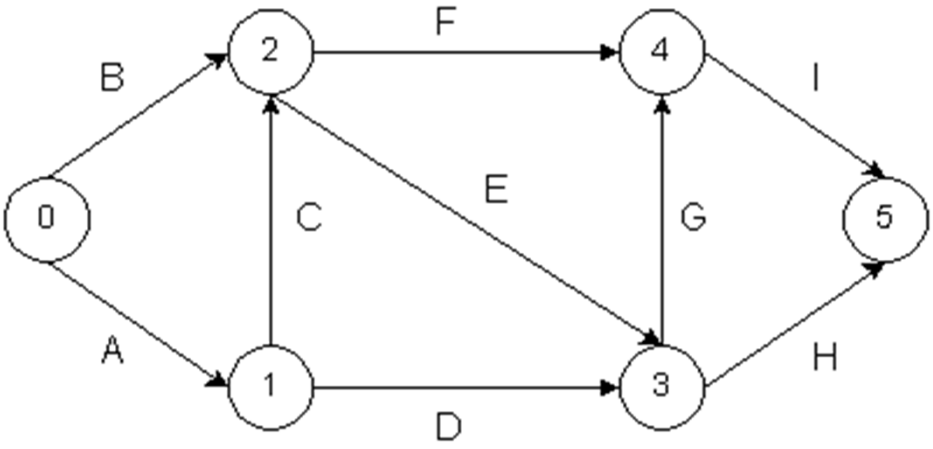
- Sometimes called “Arrow Diagramming Method” (ADM)
- A schedule network diagramming method in which schedule activities are represented by arrows.
- The tail of the arrow represents the start, and the head represents the finish of the schedule activity.
- The length of the arrow does not represent the expected duration of the schedule activity
- Schedule activities are connected at points called nodes (usually drawn as small circles) to illustrate the sequence in which the schedule activities are expected to be performed
- Activities are represented by Arrows. Events (points in time) are represented by Nodes.

Activity on Arrow (CPM) II

Example: Nine-Activity Project

Activity	Description	Predecessors
A	Site clearing	-
B	Removal of trees	-
C	General excavation	A
D	Grading general area	A
E	Excavation for utility trenches	B, C
F	Placing formwork and reinforcement for concrete	B, C
G	Installing sewer lines	D,E
H	Installing other utilities	D,E
I	Pouring concrete	F,G

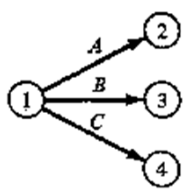
Activity on Arrow (CPM) III



Activity on Arrow (CPM) IV

- **Rules for Constructing a CPM Network:**

1. Draw arrows from left to right.
2. Each activity must have a unique i-j number



Activity on Arrow (CPM) V

3. May use dummy activities when needed

   Dummy Activity: is indicated by a dashed line arrow & requires neither time nor resources but is needed to properly show the logic.

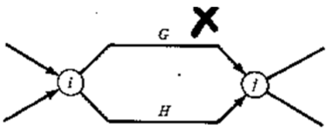


FIGURE 12-19
Incorrect notation for concurrent activities.

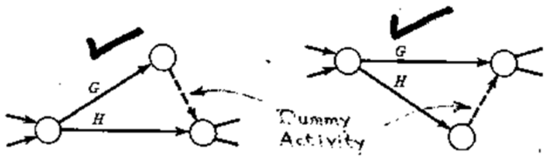
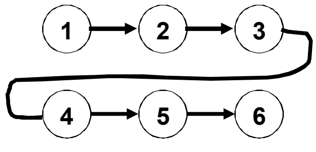
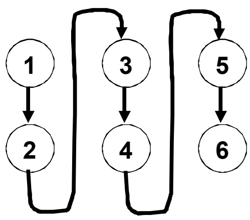


FIGURE 12-20
possibilities of G-H with dummy arrow.

Activity on Arrow (CPM) VI

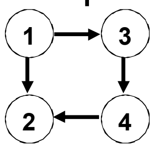
4. j > i.
5. Always number the nodes after the diagram is completed.
6. Event numbers should be assigned in a regular format (i.e. horizontal or vertical formats).

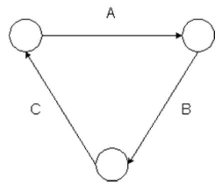




Activity on Arrow (CPM) VII

7. Avoid illogical loops.





8. Minimize crossovers whenever possible.

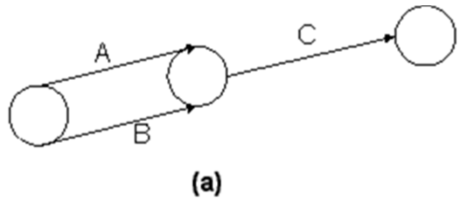
Crossovers

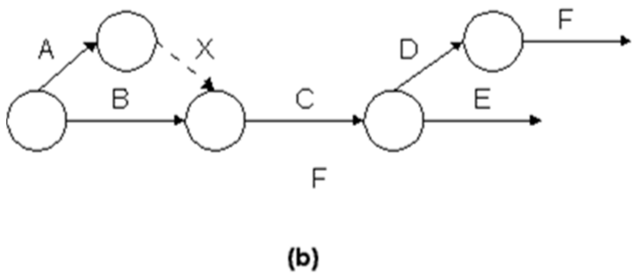
Activity on Arrow (CPM) VIII

- **Example:**

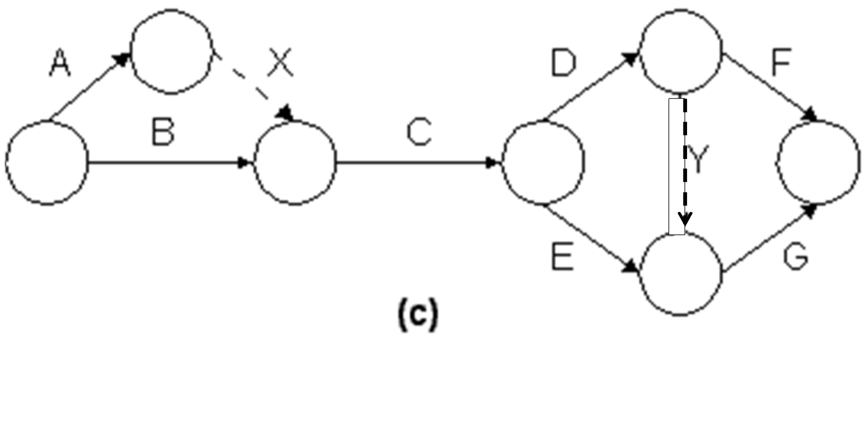
Activity	Predecessors
A	-
B	-
C	A, B
D	C
E	C
F	D
G	D,E

Activity on Arrow (CPM) IX



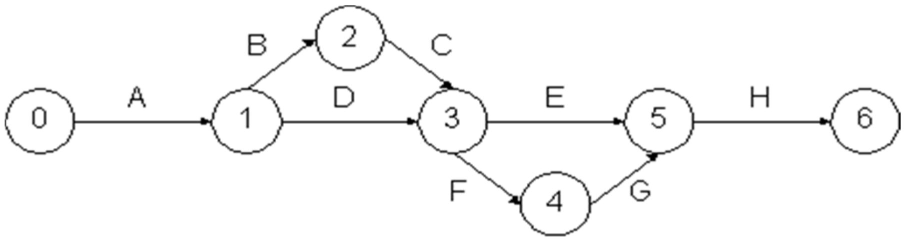


Activity on Arrow (CPM) X



Activity on Arrow (CPM) XI

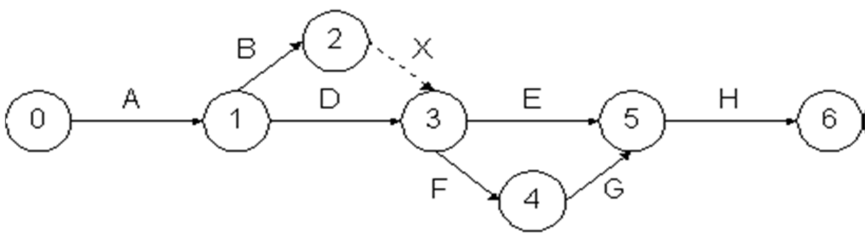
- Consider this example if we remove activity C



(a)

Activity on Arrow (CPM) XII

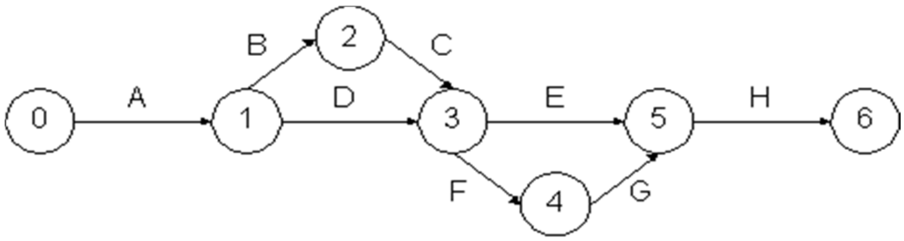
- A dummy activity needs to be used



(b)

Activity on Arrow (CPM) XIII

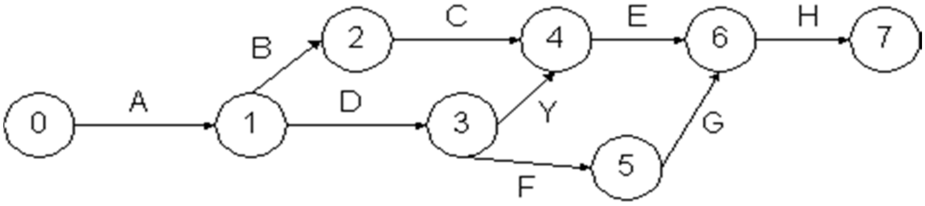
- **Consider the same example if activity E cannot start until both C and D are completed but that F can start after D alone is completed**



(a)

Activity on Arrow (CPM) XIV

- **A dummy activity needs to be used**



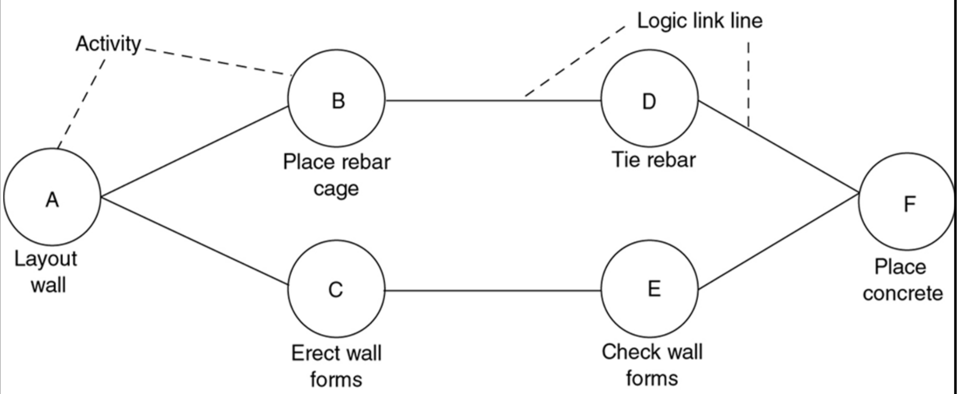
(c)

Precedence Diagram I

- The most common type of network schedule in use today is the precedence diagram
  - A series of nodes with lines (links) connecting them to illustrate activities
  - Activities are represented by nodes, drawn in any desired shape
  - Lines represent “Activity links,” used to represent dependencies between activities
  - The precedence diagram is “read” from left to right

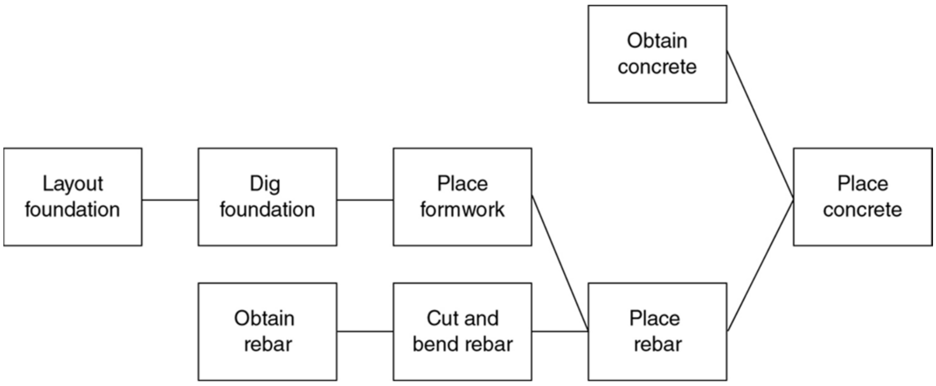
Precedence Diagram II

- Simple Example of a Precedence Diagram for Erecting a Concrete Wall



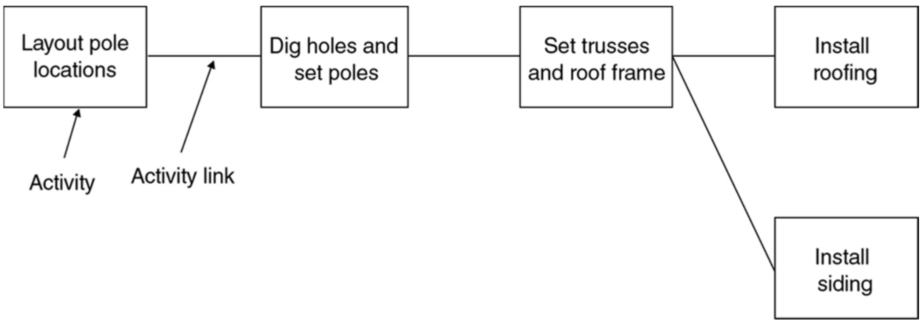
Precedence Diagram III

- Example of a Precedence Diagram for Constructing a Concrete Footing



Precedence Diagram IV

- A preliminary or rough network can be generated by positioning each activity relative to other activities and drawing lines between each set of related activities



Precedence Diagram V

- **Example:**

Activity	Predecessors
A	-
B	-
C	A, B
D	C
E	C
F	D
G	D,E

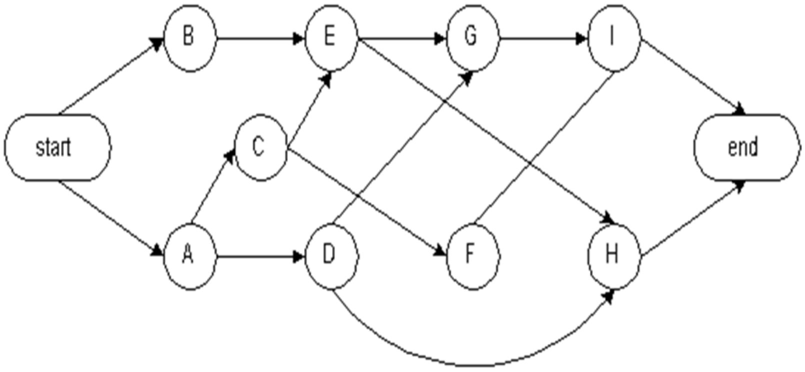
Precedence Diagram VI

Example: <u>Nine-Activity Project</u>

Activity	Description	Predecessors
A	Site clearing	-
B	Removal of trees	-
C	General excavation	A
D	Grading general area	A
E	Excavation for utility trenches	B, C
F	Placing formwork and reinforcement for concrete	B, C
G	Installing sewer lines	D,E
H	Installing other utilities	D,E
I	Pouring concrete	F,G

Precedence Diagram VII

Example: Nine-Activity Project



Basics about Precedence Diagrams

- Do not confuse the link lines with activities
- Nodes or precedence activities can be denoted simply by a single character
  - Generally customized to the user's convenience

Act. I.D. #	Activity Description		Activity Cost
SS	Activity Duration		SF
FS	Activity Resources		FF
ES	LS	EF	LF
FF	TF	Int. F	Ind. F

Example Node Designation

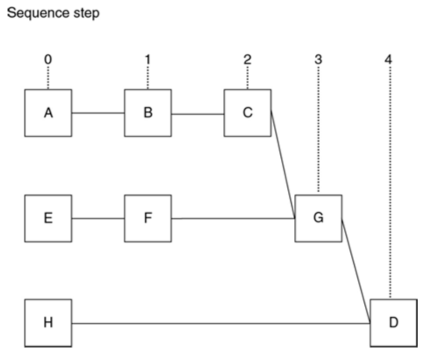
Activity			
	Duration		LS
	FF	TF	LF

Simplified Format for
a Precedence Activity

Basics about Precedence Diagrams

- A more systematic approach uses sequence steps
  - Each activity is assigned to a particular sequence step

Activity	IPAs	Sequence Step
A	-	0
B	A	1
C	B	2
D	G, H	4
E	-	0
F	E	1
G	C, F	3
H	-	0



Basics about Precedence Diagrams

- **PDM Characteristics:**
  - –Activities are represented by Nodes.
  - –Logical relationships are represented by Arrows.
  - –Single unique number for each activity (e.g. 100).
  - –No dummy activities.

Construction Project Management
(CE 110401346)

4. Network Calculations

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Calculations On a Precedence Network I

- **Early Activity Start (ES):** Earliest time an activity can start—as determined by the latest of the early finish times of all immediate preceding activities (IPAs)
- **Early Activity Finish (EF):** Earliest time an activity can finish—determined by adding the duration of the activity to the early start time
- **Late Activity Start (LS):** Latest time an activity can start without delaying the project completion
- **Late Activity Finish (LF):** Latest time an activity can be finished without delaying project completion

Calculations On a Precedence Network II

- **Early Event Occurrence Time:** Earliest an event can occur—determined by the latest early finish
- **Late Event Occurrence Time**: Latest an event can occur

Calculations On a Precedence Network III

- **Step 1:** Perform Forward Pass Calculations to determine:
  - Early Start (ES) and Early Finish (EF) of each activity.

    ES (initial activities) = S

    ES (x) = Latest (EF (all predecessors of x))

    EF (x) = ES(x) + D(x)

    Where,

    S= Project start time.

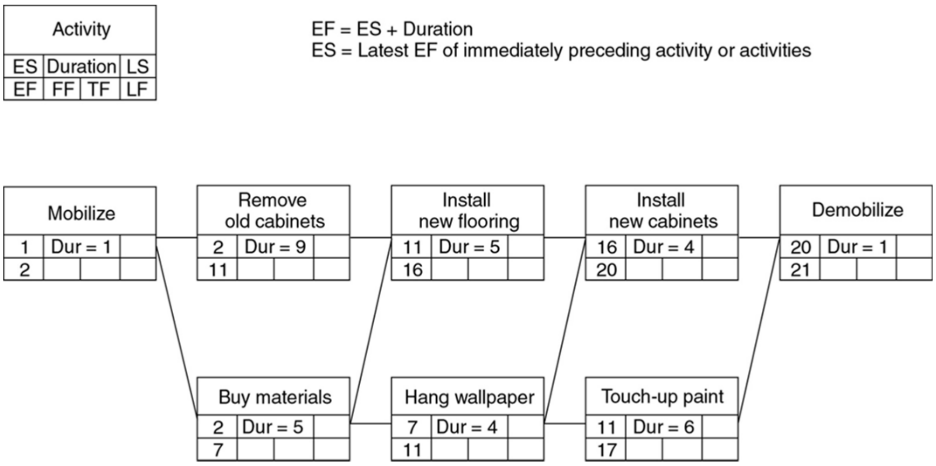
    D(x) = Duration of activity x.

    ES(x)= Earliest start time of activity x.

    EF(x) = Earliest finish time of activity x.

Calculations On a Precedence Network IV

Illustrating computations on a precedence diagram
All relationships are assumed to be Finish-to-Start



Early Times (Early Start [ES] and Early Finish [EF])

Calculations On a Precedence Network V

- 1. Assign 1 as the early start date of the first activity
- 2. Calculate the early finish time for the activity
- 3. The early start of activities will be determined by the early finish times of preceding activities
  - Other than the first activity or activities
- 4. Repeat steps 2 and 3 for each network activity until **ES** & **EF** are determined for the last activity

Calculations On a Precedence Network VI

- **Step 2:** Perform Backward Pass Calculations to determine:
  – Late Start (LS) and Late Finish (LF) of each activity.

LF (end activities) = T

LF (x) = Earliest (LS (all successors of x))

LS (x) = LF(x) - D(x)

Where,

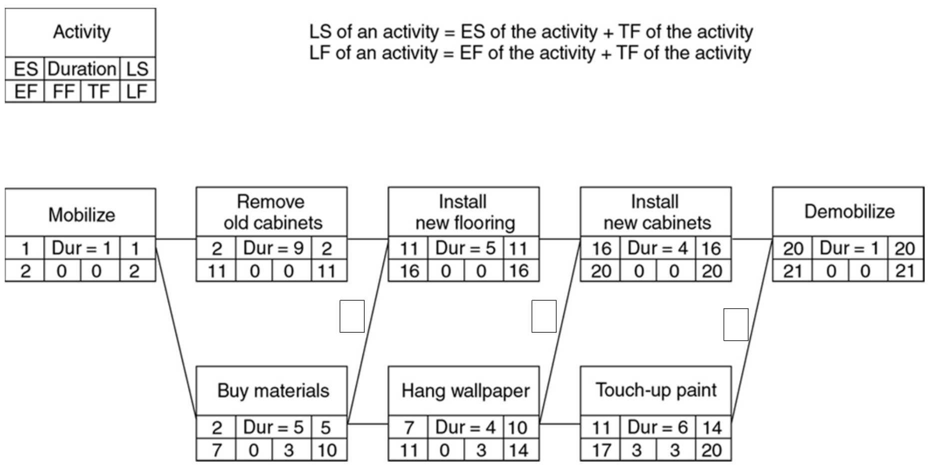
T = Project completion time.

D(x) = Duration of activity x.

LS(x) = Latest start time of activity x.

LF(x) = Latest finish time of activity x.

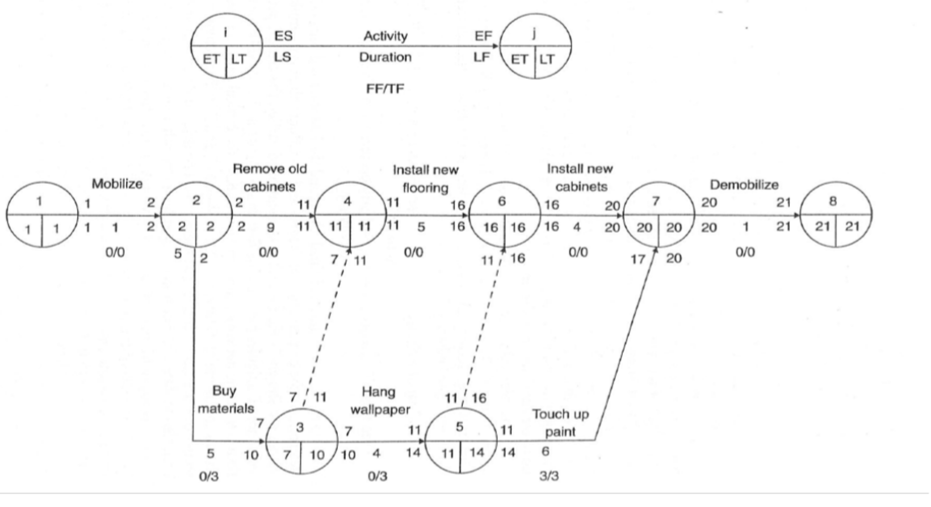
Calculations On a Precedence Network VII



Calculations On a Precedence Network VIII

Activity	TF	FF	IF
Mobilize	0	0	0
Remove old Cabinets	0	0	0
Buy materials	3	0	0
Install new flooring	0	0	0
Hang wallpaper	3	0	-3
Install new cabinets	0	0	0
Touch-up paint	3	3	0
Demobilize	0	0	0

Calculations On a Arrow Network



Identify the Critical Path

- When an activity start date is fixed in this way, the activity is said to have no float
- Such activities are said to be “critical”
  - If the activity starts later than the assigned date, or takes longer to complete than the assigned duration, the project completion date will be extended by the same amount of time

Activity Floats I

- **Total Float (TF):** maximum amount of time that the activity can be delayed without delaying the completion time of the project.
- **Free Float (FF)**: maximum amount of time that the activity can be delayed without delaying the early start of any of its successors, assuming its predecessors were completed early.
  - **Free Float:** Amount of time an activity can be delayed before it impacts the start of any succeeding activity

Activity Floats II

- **Independent Float (IF):** maximum amount of time that the activity can be delayed without delaying the early start of any of its successors, assuming its predecessors were completed late.

Activity Floats III

		Successors Started	
		Early	**Late**
Predecessors Completed	**Early**	**Free Float**	**Total Float**
	Late	**Independent Float**	

Activity Floats IV

Float Type	Calculation
Total Float	TF = LS – ES TF = LF – EF
Free Float	FF = Min (ES of all successors) – EF
Independent Float	IF = Min (ES of all successors) – Max (LF of all predecessors) – D

Calculations On a Precedence Network IX

- **Once the early and late start times, early and late finish times, free float, and total float of all activities are determined, the calculations are completed**

Calculations On a Precedence Network X

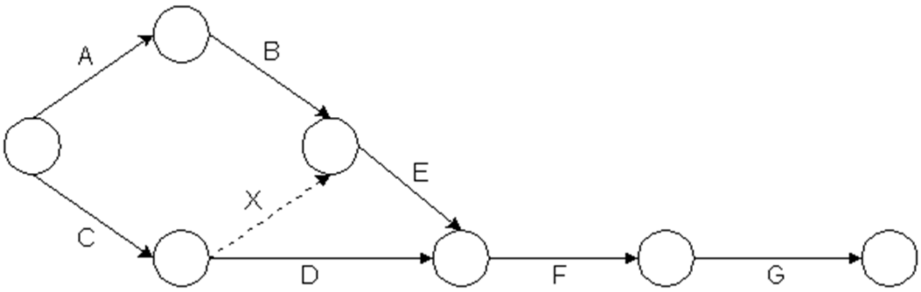
- **LAG:** The amount of time that exists between the early finish of an activity and the early start of a specified succeeding activity

$$(LAG_{AB} = ES_B - EF_A)$$

Example 2: Network Calculations I

Activity	Description	Predecessors	Duration
A	Preliminary design	-	6
B	Evaluation of design	A	1
C	Contract negotiation	-	8
D	Preparation of fabrication plant	C	5
E	Final design	B, C	9
F	Fabrication of Product	D, E	12
G	Shipment of Product to owner	F	3

Example 2: Network Calculations II



Example 2: Network Calculations III

Activity	Duration	ES	EF	LS	LF
A	6				
B	1				
C	8				
D	5				
E	9				
F	12				
G	3				

Example 2: Network Calculations III

Activity	Duration	ES	EF	LS	LF
A	6	1	7	2	8
B	1	7	8	8	9
C	8	1	9	1	9
D	5	9	14	13	18
E	9	9	18	9	18
F	12	18	30	18	30
G	3	30	33	30	33

Example 2: Network Calculations IV

Activity	Duration	ES	EF	LS	LF	TF	FF	IF
A	6	1	7	2	8			
B	1	7	8	8	9			
C	8	1	9	1	9			
D	5	9	14	13	18			
E	9	9	18	9	18			
F	12	18	30	18	30			
G	3	30	33	30	33			

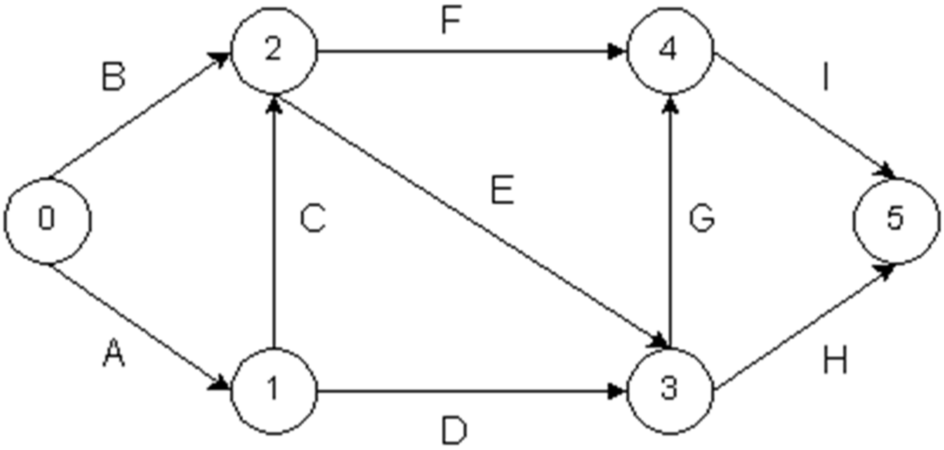
Example 2: Network Calculations IV

Activity	Duration	ES	EF	LS	LF	TF	FF	IF
A	6	1	7	2	8	1	0	0
B	1	7	8	8	9	1	1	0
C	8	1	9	1	9	0	0	0
D	5	9	14	13	18	4	4	4
E	9	9	18	9	18	0	0	0
F	12	18	30	18	30	0	0	0
G	3	30	33	30	33	0	0	0

Example 3: Network Calculations I

Activity	Description	Predecessors	Duration
A	Site clearing	-	4
B	Removal of trees	-	3
C	General excavation	A	8
D	Grading general area	A	7
E	Excavation for utility trenches	B, C	9
F	Placing formwork and reinforcement for concrete	B, C	12
G	Installing sewer lines	D,E	2
H	Installing other utilities	D,E	5
I	Pouring concrete	F,G	6

Example 3: Network Calculations II



Example 3: Network Calculations III

Activity	Duration	Early Start	Early Finish	Late Start	Late Finish
A	4				
B	3				
C	8				
D	7				
E	9				
F	12				
G	2				
H	5				
I	6				

Example 3: Network Calculations III

Activity	Duration	Early Start	Early Finish	Late Start	Late Finish
A	4	1	5	1	5
B	3	1	4	10	13
C	8	5	13	5	13
D	7	5	12	16	23
E	9	13	22	14	23
F	12	13	25	13	25
G	2	22	24	23	25
H	5	22	27	26	31
I	6	25	31	25	31

Example 3: Network Calculations IV

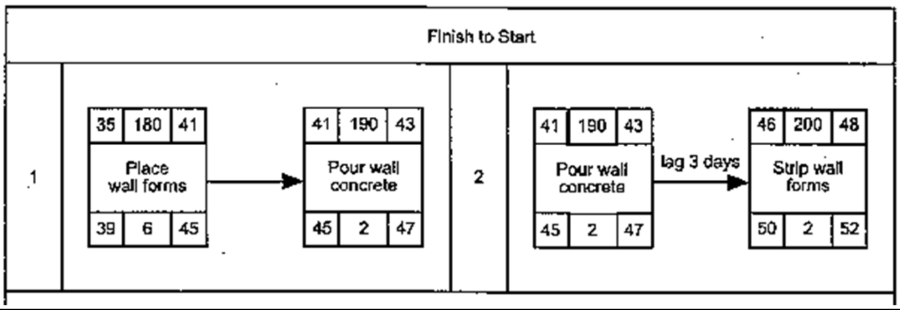
Activity	Duration	ES	EF	LS	LF	TF	FF	IF
A	4	1	5	1	5			
B	3	1	4	10	13			
C	8	5	13	5	13			
D	7	5	12	16	23			
E	9	13	22	14	23			
F	12	13	25	13	25			
G	2	22	24	23	25			
H	5	22	27	26	31			
I	6	25	31	25	31			

Example 3: Network Calculations IV

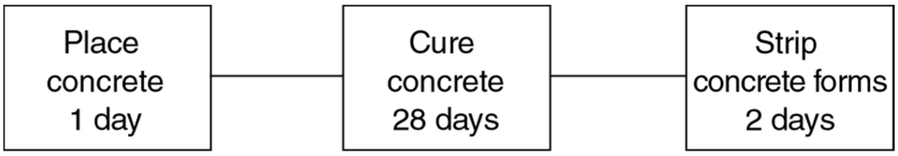
Activity	Duration	ES	EF	LS	LF	TF	FF	IF
A	4	1	5	1	5	0	0	0
B	3	1	4	10	13	9	9	9
C	8	5	13	5	13	0	0	0
D	7	5	12	16	23	11	10	10
E	9	13	22	14	23	1	0	0
F	12	13	25	13	25	0	0	0
G	2	22	24	23	25	1	1	0
H	5	22	27	26	31	4	4	3
I	6	25	31	25	31	0	0	0

Precedence Diagram Relationships I

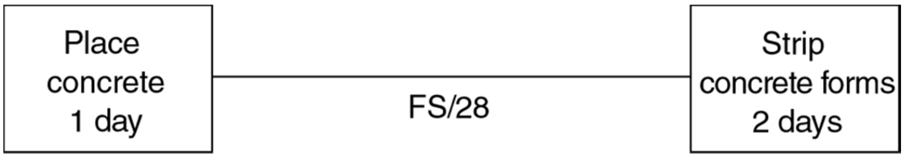
- **Types of Logical Precedence Relationships in PDM**
  - Finish to Start (with or without lag):
    - Each activity depends on the completion of its preceding activity



Precedence Diagram Relationships II



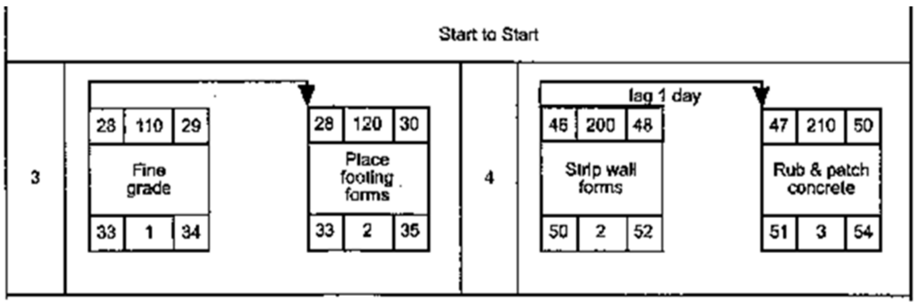
Typical Sequence of Finish-to-Start Relationships



Finish-to-Start Relationship with a 28-Day Delay (lag)

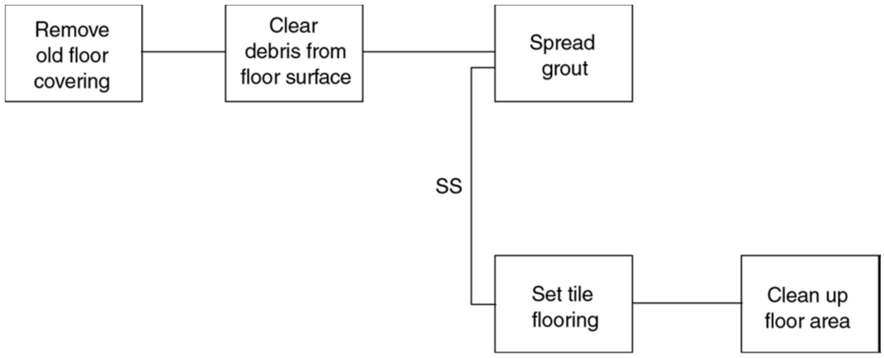
Precedence Diagram Relationships III

- **Types of Logical Precedence Relationships in PDM**
  - Start to Start (with or without lag).



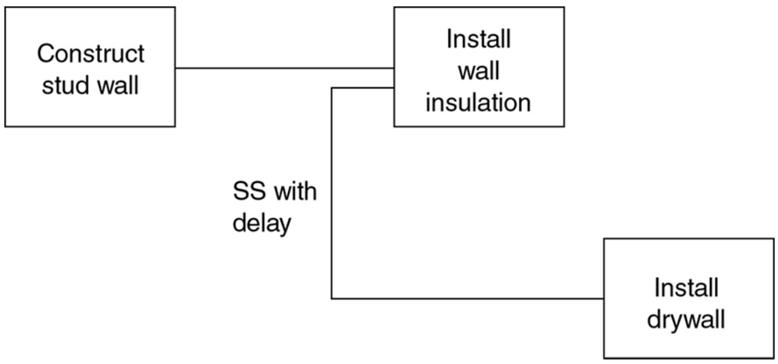
Precedence Diagram Relationships IV

Activities with Start-to-Start Relationships



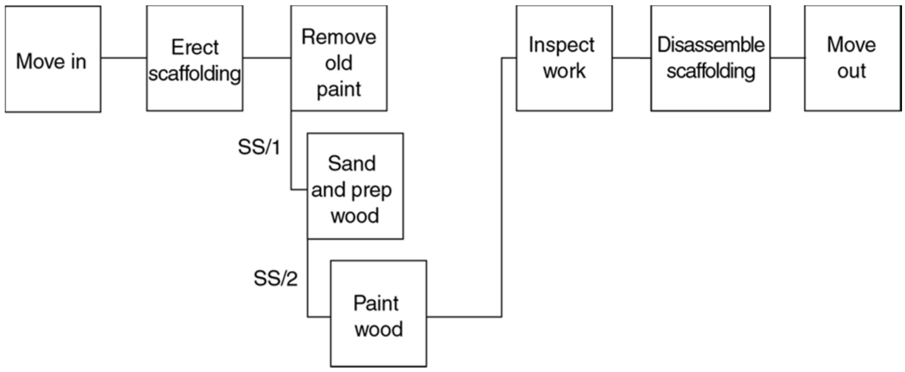
Precedence Diagram Relationships V

Activities with Start-to-Start with a Delay Relationships



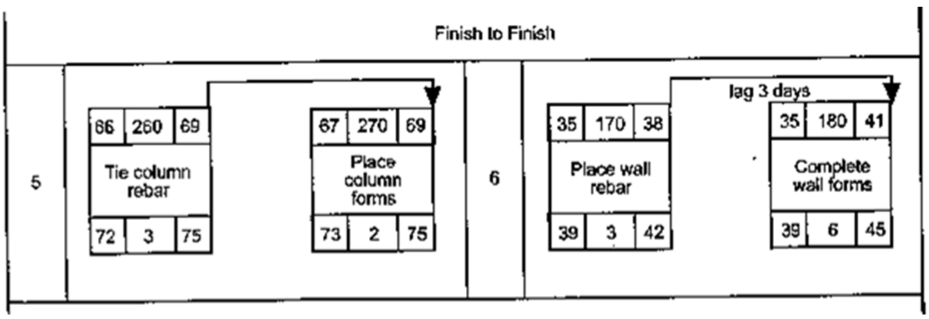
Precedence Diagram Relationships VI

Activities with Start-to-Start with a Delay Relationships

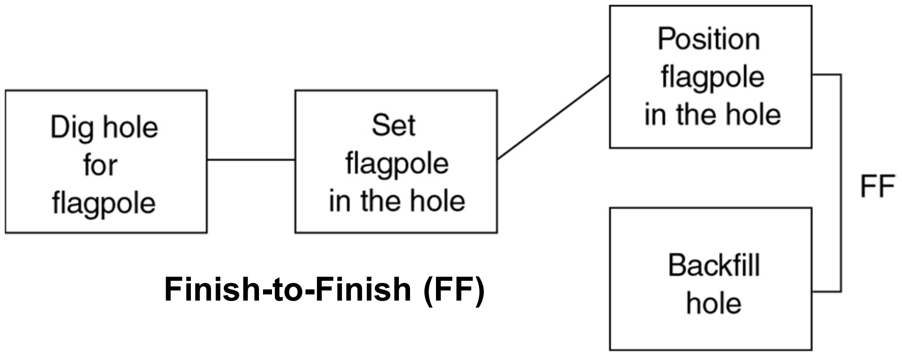


Precedence Diagram Relationships VII

- **Types of Logical Precedence Relationships in PDM**
  - Finish to Finish (with or without lag).

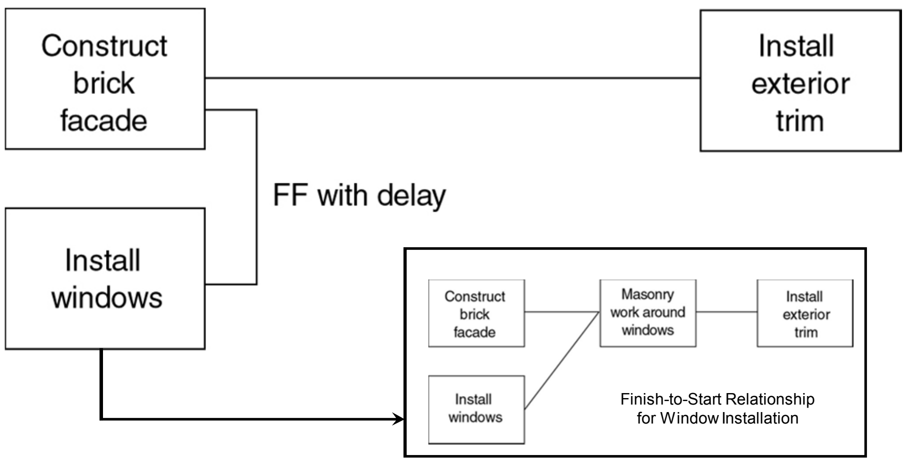


Precedence Diagram Relationships VIII



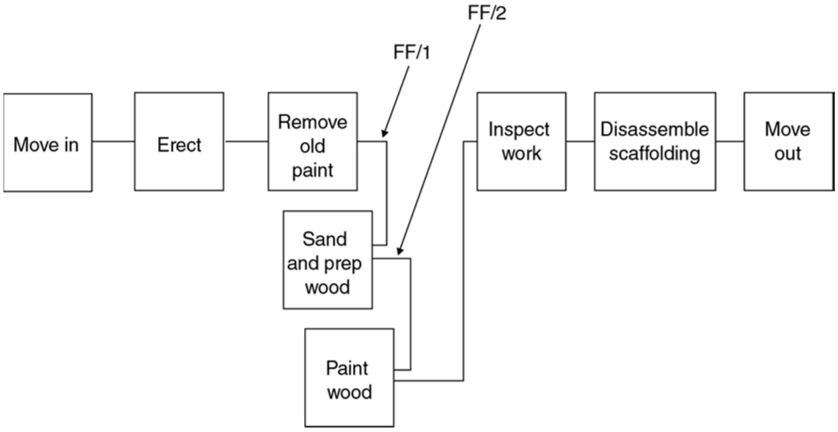
Precedence Diagram Relationships IX

Finish-to-Finish (FF) — with Delay



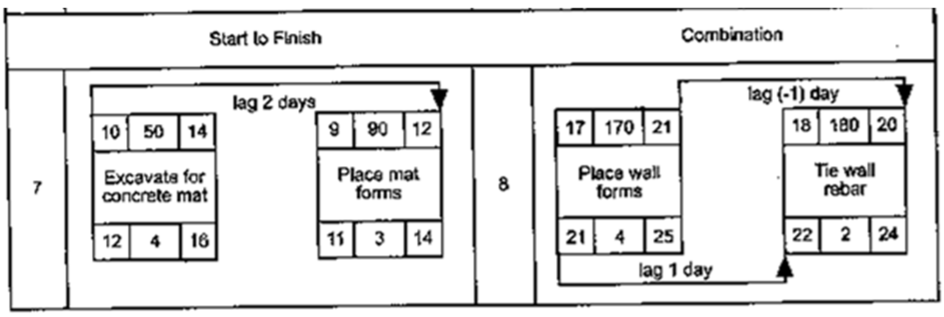
Precedence Diagram Relationships X

Activities with Finish-to-Finish with a Delay (lag) Relationships



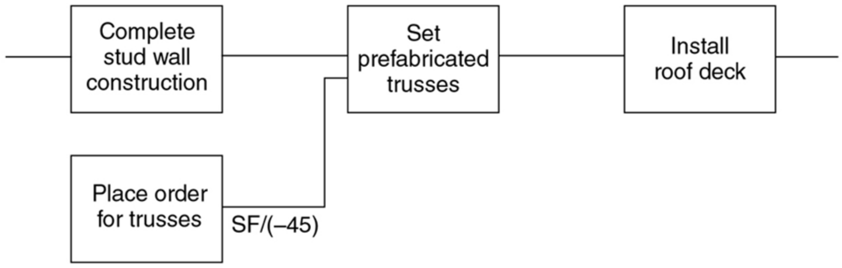
Precedence Diagram Relationships XI

- **Types of Logical Precedence Relationships in PDM**
  - Start to Finish (with or without lag).



Precedence Diagram Relationships XII

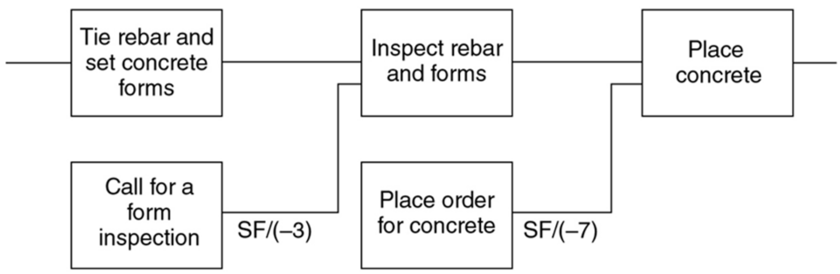
Start-to-Finish with a Delay — Relationships



(a) Start-to-finish with delay relationship for long lead-time purchases

Precedence Diagram Relationships XIII

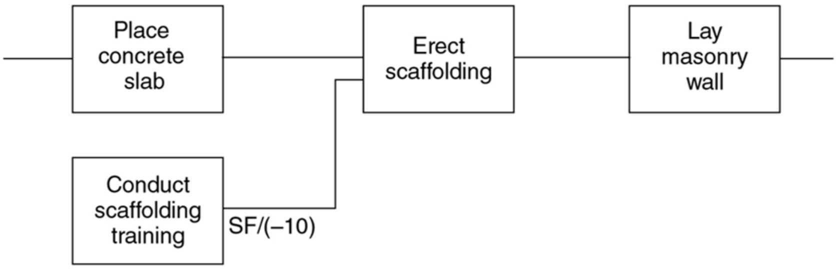
Start-to-Finish with a Delay — Relationships



(b) Start-to-finish relationship for requested inspections and for specific delivery times

Precedence Diagram Relationships XIV

Start-to-Finish with a Delay — Relationships



(c) Start-to-finish relationship involving training

Precedence Diagram Method

- **Advantages of PDM Over CPM:**
  - Easier to construct & modify network.
  - No need for dummies.
  - Less activities in presentation.
  - Precedence relationships with lag times are more effective in modeling project activities.

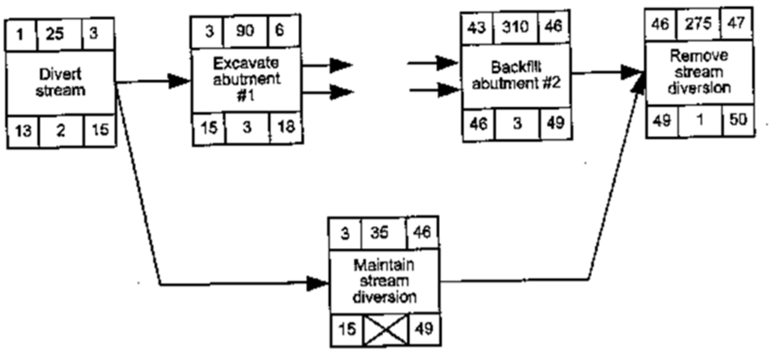
Types of Activities

- **Milestones:** are points in time that are identified as important intermediate dates.
  - **Example:** a weather-imposed date to finish exterior activities.
- **Schedule Milestone** : A significant event in the project schedule, such as an event restraining future work or marking the completion of a major deliverable
- A schedule milestone has zero durations

Types of Activities II

Hammock Activity: an activity that extends from one activity to another but has no duration of its own.

Example: Dewatering activity.



Highway bridge, hammock activity.

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4a – Practice Examples

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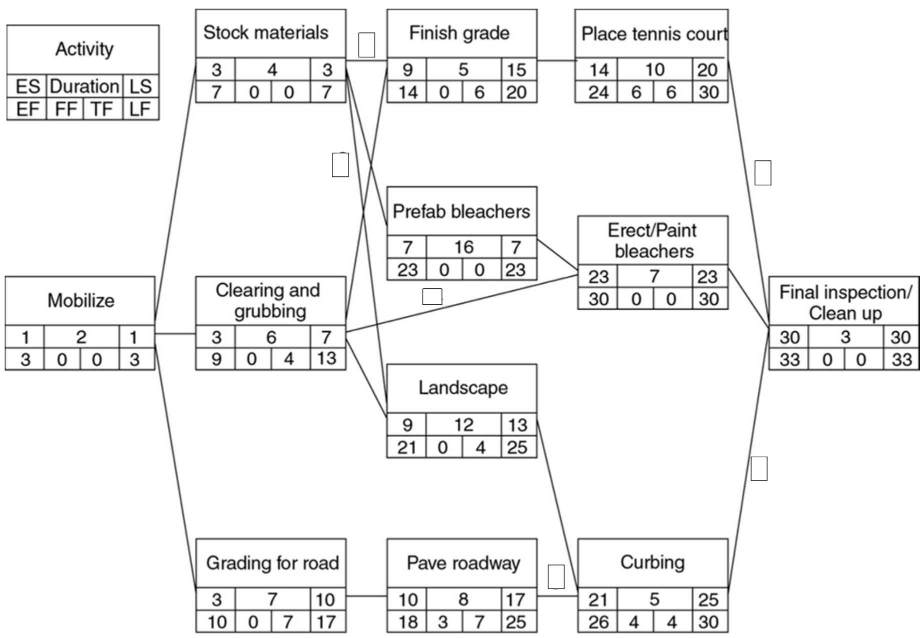
Constructing a tennis court facility



Constructing a tennis court facility

Activity	Duration	ES	EF	LS	LF	TF	FF	IF
Mobilize	2							
Stock materials	4							
Clearing and grubbing	6							
Grading for road	7							
Finish grade	5							
Prefab bleachers	16							
Landscape	12							
Pave roadway	8							
Place tennis court	10							
Erect/Paint bleachers	7							
Curbing	5							
Final inspection/ Clean up	3							

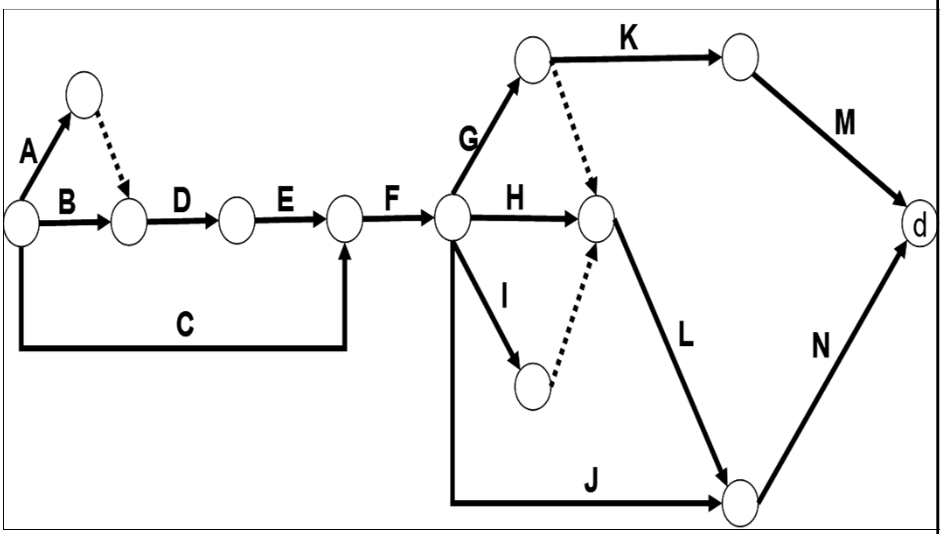
Example 2 (AOA)

Activity	Predecessors	Followers
A	—	D, E
B	—	G, H, K
C	—	F
D	A	L
E	A	G, H
F	C	K
G	B, E	L, M
H	B, E	L, M
K	B, F	—
L	D, G, H	—
M	G, H	—

Example 2

Label	Description	Duration (Weeks)	Followers
A	Survey Site	1	D
B	Mobilize	2	D
C	Obtain Steel	10	F
D	Grade	3	E
E	Footings	6	F
F	Erect Steel	4	G, H, I, J
G	Siding and Roofing	3	K, L
H	Erect Crane	1	L
I	Cast Slab	4	L
J	Install Lights	2	N
K	Interior Walls	3	M
L	Set Equipment	2	N
M	Doors and Trim	3	-
N	Conduit and Wire	5	-

Example 2



Example 2

Label	Duration (Weeks)	ES	EF	LS	LF	TF	FF	IF
A	1							
B	2							
C	10							
D	3							
E	6							
F	4							
G	3							
H	1							
I	4							
J	2							
K	3							
L	2							
M	3							
N	5							

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5. Leadership in Project Management

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Project Management Leadership: Why?

- In the Civil Engineering Profession
  - As you grow up in your organization (construction company, design firm, etc.) and seek project management responsibilities, an increasing amount of your work will involve leading others to accomplish the many project functions.

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Project Manager

- The project manager's ability to lead his or her people effectively can have a significant impact on the success of a project
- How to lead people in order to arrive at a successful project?
- Are leaders born or made?

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Are Leaders Born or Made?

- There are a relatively few natural born leaders
- Almost anyone can become a good leader with hard work, learning, and practice
- Leadership proficiency can be learned
- You can improve your performance as a leader by effectively following what the outstanding leaders do to be successful

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Leadership Definition

- Leadership: The process of influencing individuals or groups to accomplish an organization goal or mission
  - Leadership is a process: it is not a one-time, fire and forget evolution. To be an effective leader, you must continually exercise good leadership skills. You don't need to be perfect, but you should always strive to apply leadership principles to your leadership efforts.

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Leadership Definition II

- It involves influencing individuals or groups. Good leaders are effective influencers of others because they know leaders can't do everything

- Good leadership is designed to accomplish an organizational goal or mission. Leading your project team and managing your project to a high quality, on time, and within budget conclusion with a customer who is happy with that conclusion.

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Boss vs. Leader

- The boss drives his/her team; the leader coaches them.
- The boss depends upon authority; the leader depends upon good will.
- The boss inspires fear; the leader inspires enthusiasm.
- The boss says, "I"; the leader says "WE."
- The boss assigns the tasks; the leader sets the pace.
- The boss says, "Get here on time"; the leader begins on time.

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Boss vs. Leader II

- The boss fixes the blame for the breakdown; the leader fixes the breakdown.
- The boss knows how it is done; the leader shows how it is done.
- The boss makes work like uphill struggle; the leader makes it a game.
- The boss says, "GO"; the leader says, "LET'S GO."

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Leadership Competency

- Competency: Any knowledge, skill, behavior, attitude, or characteristic that can be shown to distinguish reliably between effective and less effective job performance
- Competency is what superior performers do more often, in more situations, and for better results, than average performers

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Outstanding Leader Competencies

1. Sense of responsibility
2. Positive expectations
3. Informed judgment
4. Conceptualization
5. Use of multiple influence strategies
6. Leader influence
7. Careful use of discipline
8. Effective communication
9. Planning
10. Initiative
11. Monitoring for results

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1. Sense of Responsibility

- The outstanding leader has an obvious sense of responsibility toward his or her people and toward his or her project.
- Indicators or behaviors associated with Sense of Responsibility:
  - Take responsibility for own and team's performance, including failures or problems
  - Take responsibility for team's reputation or image
  - Take responsibility for the safety and well-being of team members in job-related activities
  - Take actions to support the member's responsibilities towards his/her family

1. Sense of Responsibility II

- Examples to show support when a team member has family needs:
  - Time off for personal crises
  - Phone calls to check on a sick family member
  - Shifting work load temporarily to meet a temporary crisis
  - Thank you note to spouse or family thanking them for their support of an associate during a period of long and/or hectic work hours

2. Positive Expectations

- The outstanding leader starts with a positive mindset about his or her people
- His or her positive expectations are based on respect for people’s dignity and self worth.
- The expectations is that when people are treated well they will do well
- The following are ways in which outstanding leaders display positive expectations toward their people:
  - Has a strong confidence that subordinates are valuable resources
  - Acknowledges a person’s strengths as well as shortcomings (balanced perspective)
  - Directly express to people the belief that they can and will succeed

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3. Informed Judgment

- The outstanding leader tends to keep a cool head, press for facts, strive for objectivity and seeks to reach sound conclusions when a problem occur:
  - Forms opinions and make decisions on information and the identification of available facts
  - Makes decisions or draws conclusions using data and information from own and other’s experiences

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4. Conceptualization

- It allows the leader to take cues (signs or signals) and organize them into wholes (concepts)
- It allows the leader to see patterns and sort relevant information from irrelevant information.

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4. Conceptualization II

- Indicators or behaviors associated with Conceptualization:
  – Identifies multiple causes of an event, situation, or behavior (e.g. a late deliverable)
  – Interprets meaning of nonverbal cues (a facial expression, a walk)
  – Identifies trends in events or patterns of behavior
  – Identifies commonalities or patterns between old and new situations
  – Identifies key differences among situations or between opposing viewpoints
  – Grasps and communicates ideas or situations through the use of metaphors and analogies when appropriate

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5. Use of Multiple Influence Strategies

- Examples of influencing strategies to influence project team as well as others within and outside the organization:
  - Establishes credibility as a leader by displaying own expertise and professionalism
  - Leads by example, Influences by consciously modeling expected behavior
  - Influences by appeal to higher purpose (Customer, team, company, family)
  - Structure situations or environment to influence people's attitude or behavior (more or less formal as appropriate)
  - Build and maintain relationships (customer, boss, other leaders, etc) for the purpose of accomplishing organizational goals

6. Leader Influence

- Involves the leader using his or her status as project manager to influence others in a very personal way. It can be considered "close-in" influence
  - Leader visits shops or work areas, or otherwise makes self available or visible with the express purpose of showing interest, concern, or appreciation
  - Leader uses symbols to increase morale, loyalty, or a sense of belonging to the project or team
  - Leader publicly recognizes superior individual or group performance

6. Leader Influence II

– Communicates standards and expectations through consistent reinforcement of project and company standards (e.g. mission statement, core values). These standards are reinforced in words, at gatherings, at promotions, meetings, etc.

7. Careful Use of Discipline

- It is an inescapable truth that one facet of a leader’s job is to hold people accountable for results and to enforce company standards
- It is the leader’s attempt to help a person who is not performing well to rise up and meet or exceed accepted company and project standards
- It is also the leader’s intent to let others on the project team know that continued substandard performance will not be tolerated

7. Careful Use of Discipline II

- Behaviors associated with outstanding leaders with respect to this competency:
  - Enforces company and project standards
  - Despite a concern for the individual's future, the outstanding leader will exercise disciplinary power when harm to project or team appears likely
- Many organizations have what is called a "Progressive discipline policy":
  - Verbal warnings
  - Written warnings
  - A final warning
  - Dismissal from the company

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8. Effective Communication

- It is impossible to lead people if they do not understand you.
- Poor communication between the leader and his or her people can lead to lack of understanding of the mission, values, standards and expectations of the leader and the organization

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8. Effective Communication II

- Behaviors and skills associated with this competency:
  - Explains why, shares information, communicates the purpose of decisions
  - Take steps to ensure that people absorb what is communicated to them (non-verbal cues, repeat-backs, observation)
  - Tailors communications to people's level of understanding (college educated, high school education, etc)

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9. Planning

- One of the most important functions a leader can do. The outstanding leaders do it well
- Skills associated with this competency:
  - Plans beyond the demands of an immediate situation or problem
  - Sets priorities
  - Identifies obstacles to progress and plans work-arounds
  - Matches people to jobs to get the best performance
  - Identifies and lines up in advance, resources (programs, people, funds) needed to achieve an objective
  - Develops an action plan to reach an objective

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10. Initiative

- The outstanding leader is proactive. He or she doesn't wait to be overtaken by events. He or she makes the events
- Behaviors associated with this competency:
  - Introduces new ideas or new procedures to the team
  - Shares good ideas or better ways to proceed with other teams
  - Acts quickly or immediately to resolve problems
  - Persists on overcoming obstacles (No good leader is a quitter)

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11. Monitoring for results

- Project managers are responsible for results.
- Outstanding leaders use the following means to determine if they have achieved the results they are seeking, and to identify actions necessary to attain the desired results.
  - Get out of the office, actively observes work progress, seeks and collects performance information
  - Evaluate performance
  - Sees the information provided by own staff, customer, business partners and other feedback as meaningful and useful. Acts on that information to improve performance

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Construction Project Management
(CE 110401346)

6a. Construction Process Optimization

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What is Optimization?

- Theory of optimization studies how to describe and attain the BEST, once one knows how to measure what is Good or Bad

Equipment Assignment Example

- Assignment of 3 available trenching machines of different capabilities to three projects which must be done concurrently.
- Assignment to be made on the basis of minimum cost to the company.

Machine	Cost of Operating ($)		
	Project C	Project D	Project E
Trencher x	12,000	20,600	6,400
Trencher Y	12,600	25,400	6,800
Trencher Z	15,800	30,600	9,200

Equipment Assignment Example II

Machine	Cost of Operating ($)			Cost Difference $
	Project C	Project D	Project E	
Trencher x	12,000	20,600	6,400	5,600
Trencher Y	12,600	25,400	6,800	5,800
Trencher Z	15,800	30,600	9,200	6,600
Cost Difference $	600	4,800	400	

- Assign Trencher Z to Project E

Equipment Assignment Example III

Machine	Cost of Operating ($)			Cost Difference $
	Project C	Project D	Project E	
Trencher x	12,000	20,600		8,600
Trencher Y	12,600	25,400		12,800
Trencher Z				
Cost Difference $	600	4,800		

- Assign Trencher Y to Project C
- Assign Trencher X to Project D
- The total of all project costs (least possible) = $42,400

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Sources of Material Example

- Four Concrete placements must be scheduled in a single day, with concrete available from three ready-mix suppliers
- Concrete prices, delivered vary depending on factors such as the distances from plants to projects, project requirements, and data on suppliers capacities

6

Sources of Material Example II

	Available Capacity, Cubic Yards	Requirements and Unit Prices			
		Project A	Project B	Project C	Project D
		Requirements, Cubic Yards			
		300	540	450	760
Plant 1	600	$69	$42	$66	$63
Plant 2	900	$60	$54	$36	$48
Plant 3	600	$75	$48	$42	$66

Sources of Material Example III

	Available Capacity, Cubic Yards	Requirements and Unit Prices				Cost Difference
		Project A	Project B	Project C	Project D	
		Requirements, Cubic Yards				
		300	540	450	760	
Plant 1	600	$69	$42	$66	$63	$21
Plant 2	900	$60	$54	$36	$48	$12
Plant 3	600	$75	$48	$42	$66	$6
Cost Difference		$9	$6	$6	$15	

- Assign 540 cubic yards from plant 1 to project B

Sources of Material Example IV

	Available Capacity, Cubic Yards	Requirements and Unit Prices				
		Project A	Project B	Project C	Project D	Cost Difference
		Requirements, Cubic Yards				
		300		450	760	
Plant 1	60	$69		$66	$63	$3
Plant 2	900	$60		$36	$48	$12
Plant 3	600	$75		$42	$66	$24
Cost Difference		$9		$6	$15	

- Assign 450 cubic yards from plant 3 to project C

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Sources of Material Example V

	Available Capacity, Cubic Yards	Requirements and Unit Prices				
		Project A	Project B	Project C	Project D	Cost Difference
		Requirements, Cubic Yards				
		300			760	
Plant 1	60	$69			$63	$6
Plant 2	900	$60			$48	$12
Plant 3	150	$75			$66	$9
Cost Difference		$9			$15	

- Assign 760 cubic yards from plant 2 to project D

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Sources of Material Example VI

	Available Capacity, Cubic Yards	Requirements and Unit Prices				
		Project A	Project B	Project C	Project D	Cost Difference
		Requirements, Cubic Yards				
		300				
Plant 1	60	$69				
Plant 2	140	$60				
Plant 3	150	$75				
Cost Difference						

- Assign to project A: 140 cubic yards from plant 2, 60 cubic yards from plant 1, and 100 cubic yards from plant 3

Sources of Material Example VII

- The minimum cost combination allocates the following:
  - 540 yd^3 from plant 1 to Project B at $42 — $22,680
  - 450 yd^3 from plant 3 to Project C at $42 — 18,900
  - 760 yd^3 from plant 2 to Project D at $48 — 36,480
  - 140 yd^3 from plant 2 to Project A at $60 — 8,400
  - 60 yd^3 from plant 1 to Project A at $69 — 4,140
  - 100 yd^3 from plant 3 to Project a at $75 — 7,500
  - Total Cost — $98,100
- No other combination of deliveries would cost less

What is Optimization?

- Theory of optimization studies how to describe and attain the BEST, once one knows how to measure what is Good or Bad.
- In order to know what is good or bad a system model has to be created

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System Modeling

- A Model: is a conceived image of reality and is often a simplification of it
- Types of models:
  - **Physical Models**: Actual physical models of reality
    - Example: models of building analyzed in wind tunnels
  - **Graphical Models**: Lines or schematic drawings.
    - Example: CPM networks
  - **Mathematical Models**: Represent the problem in mathematical terms.
    - Example: Regression models

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Optimization

- Optimization: the process by which the best solution is determined
- Optimization Goals, Objectives, and Criteria:
  - **Goals**: specify the optimization goals (example: maximize project profit)
  - **Objectives**: specify which characteristics of the system should be optimized in order to achieve the optimization goals (example: minimize cost, or maximize income)
  - **Criteria**: used to measure the degree of achieving goals an objectives

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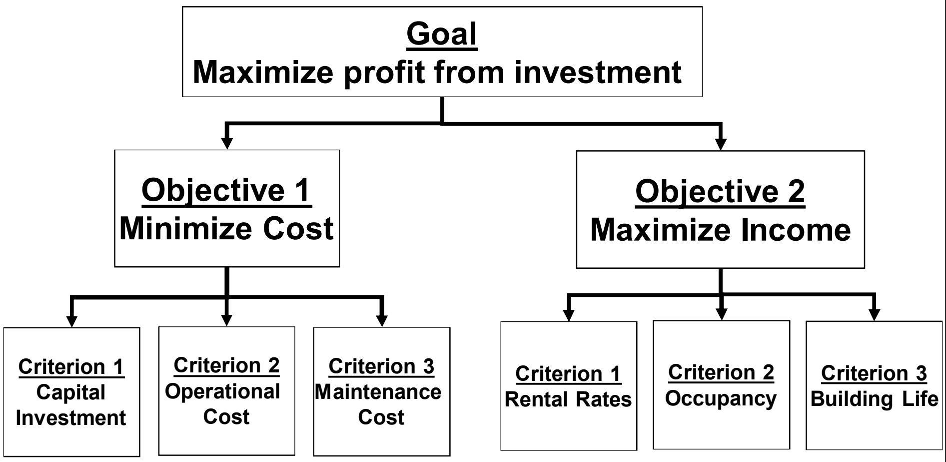
Optimization



Example: A high-rise building project

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Optimization Methods

- Analytical
  - Linear Programming
  - Non Linear Programming
- Combinatorial
  - Dynamic Programming
- Meta-Heuristics
  - Genetic Algorithms
  - Simulated Annealing
  - Tabu Search

Analytical Methods

- Applied to a totally ordered system modeled with functions in closed mathematical form
- General format:

Maximize or Minimize

$C_1 = F_1(x_1, x_2, x_3, \ldots\ldots, x_n)$

$C_2 = F_2(x_1, x_2, x_3, \ldots\ldots, x_n)$

. . . . .

$C_k = F_k(x_1, x_2, x_3, \ldots\ldots, x_n)$

Analytical Methods

Subject to the following constraints:

Lower bounds:

$G_1(x_1, x_2, x_3, \ldots\ldots, x_n) \geq a_1$

$G_2(x_1, x_2, x_3, \ldots\ldots, x_n) \geq a_2$

Upper bounds:

$H_1(x_1, x_2, x_3, \ldots\ldots, x_n) \leq b_1$

$H_2(x_1, x_2, x_3, \ldots\ldots, x_n) \geq b_2$

Equalities

$P_1(x_1, x_2, x_3, \ldots\ldots, x_n) = c_1$

$P_2(x_1, x_2, x_3, \ldots\ldots, x_n) = c_2$

Calculus Methods

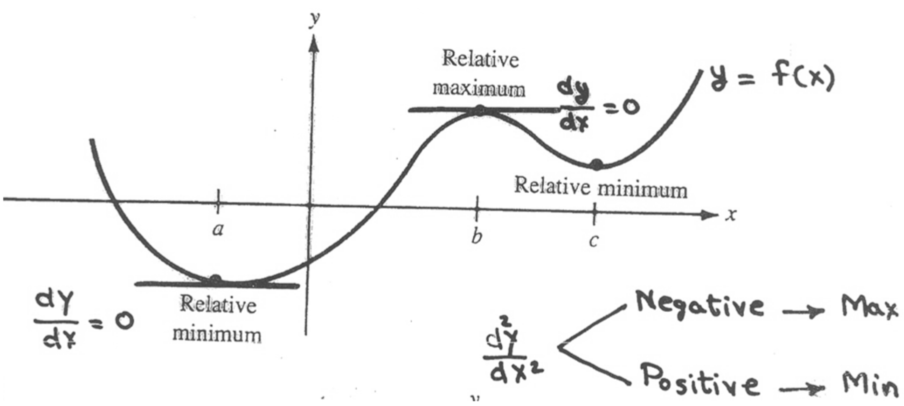
- Calculus Methods are powerful in solving optimization problems when:
  - A functional relationship can be developed between decision variables of the problem

    For example: $y = 5+5x-2x^2$
  - The function can be differentiated to provide maximum and minimum conditions

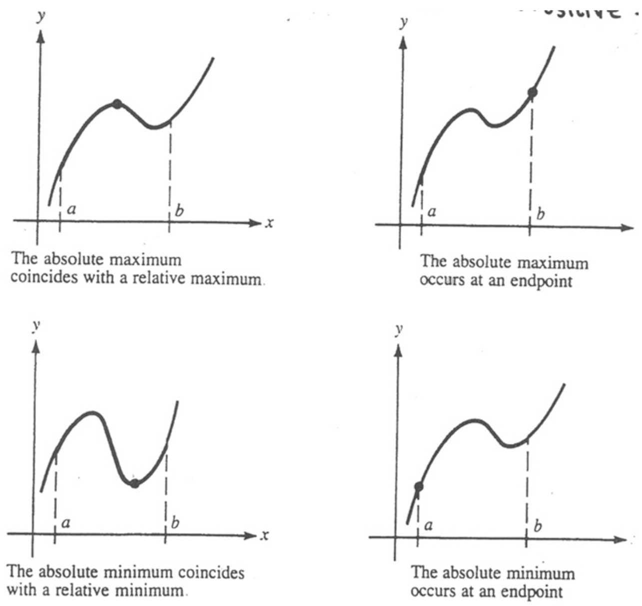
Calculus Methods

- Solutions Steps:
  1. Formulate an optimization model
  2. Find the extreme points (points of maximum and minimum) by differentiation
  3. Check for maximum or minimum conditions by taking second derivatives
  4. Check for global maximum or minimum by comparing extreme points (from step 2) to boundary or constraint limits

Calculus Methods



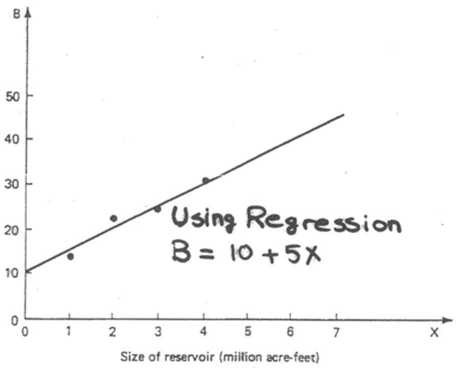
Calculus Methods

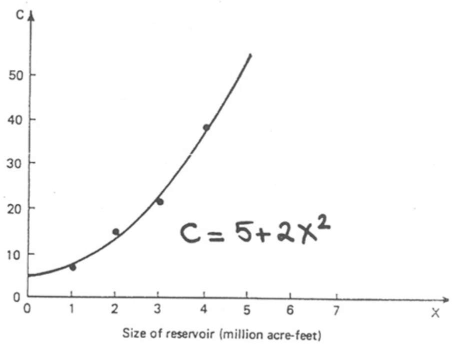


Calculus Methods (Example)

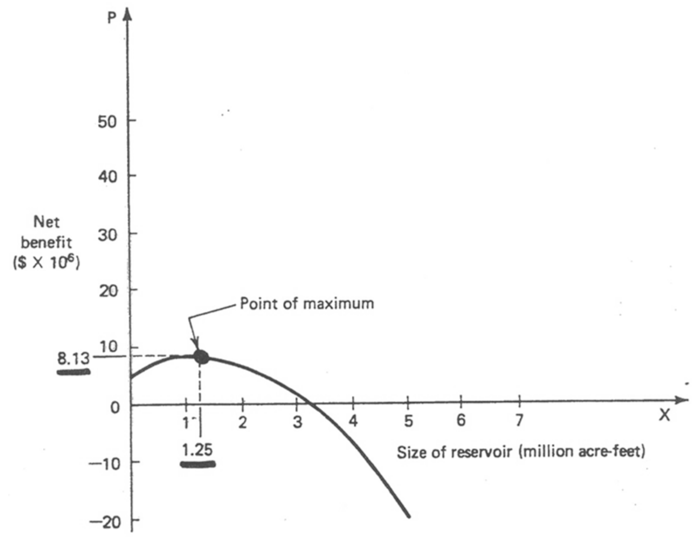
- A county is building a water reservoir and is trying to decide what is the optimum reservoir size
- The practical constraint on the size of the reservoir is that it cannot be larger than 5 million acre-feet due to the topography
- The benefits and costs in dollars from 4 different reservoir sizes have been determined and were used to find the relation between reservoir size and benefits and costs

Calculus Methods (Example)





Calculus Methods (Example)



Construction Project Management
(CE 110401346)

6b. Construction Process Optimization

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Linear Programming

- Simplest and most widely used method of optimization method.
- Requires all mathematical functions in the model to be linear.
- General Form:

  Maximize an objective function of:

  $Z= c_1x_1+c_2x_2+....+c_nx_n$

Linear Programming

Subject to the constraints of:

$a_{11}\, x_1 + a_{12}\, x_2 \ldots\ldots + a_{1n}\, x_n \leq b_1$

$a_{21}\, x_1 + a_{22}\, x_2 \ldots\ldots + a_{2n}\, x_n \leq b_2$

.

.

$a_{m1}\, x_1 + a_{m2}\, x_2 \ldots\ldots + a_{mn}\, x_n \leq b_m$

Linear Programming

More efficient form of a linear programming model

Maximize $$Z = \sum_{j=1}^{n} c_j x_j$$

Subject to: $$\sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

where i= 1,2,3, …..,m

and j= 1,2,3, …..,n

Linear Programming Steps

Step 1: Formulating an Optimization Model

a. Identify the decision variables (X_1, X_2, ….X_n) by asking:

What are we trying to decide on or find out?

Example of decision variable:

Number of units to be produced, purchased, or transported.

b. Develop a mathematical expression that represents the objective function by asking:

What are we trying to achieve?

Examples of an Objective Function:

maximize income, profit, …etc,

Linear Programming Steps II

c. Develop a mathematical expression that represents the constraints of the problem by asking:

What are the constraints imposed on the problem?

Examples of constraints:

Limited resources such as money, material, labor, equipment, etc.

Linear Programming Steps

Example problem. The N. Dustrious Company produces two products: I and II. The raw material requirements, space needed for storage, production rates, and selling prices for these products are given in Table 9.1. The total amount of raw material available per day for both products is 1575 lb,

TABLE 9.1 Production Data for N. Dustrious Company

	Product	
	I	II
Storage space (ft^2/unit)	4	5
Raw material (lb/unit)	5	3
Production rate (units/hr)	60	30
Selling price ($/unit)	13	11

the total storage space for all products is 1500 ft^2, and a maximum of 7 hours per day can be used for production. All products manufactured are shipped out of the storage area at the end of the day. Therefore, the two products must share the total raw material, storage space, and production time. The company wants to determine how many units of each product to produce per day to maximize its total income.

Linear Programming Steps

- Maximize $Z = 13 X_1 + 11X_2$
- Subject to
  - $4X_1 + 5X_2 \leq 1500$
  - $5X_1 + 3X_2 \leq 1575$
  - $X_1/60 + X_2/30 \leq 7$

Linear Programming Steps

- Step 2: Finding the Optimum Solution
  - Available Software
  - Simplex Algorithm

Example No. 2

- WyndorGlass Co. makes two products: (i) doors, and (ii) glass windows.
- They have three plants. Producing a batch of doors requires resources from multiple plants. Similarly, producing a batch of windows requires resources from multiple plants.
- The profit per batch of doors is $5,000 and profit per batch of windows is $3000.
- Wyndor wants to decide the number of batches of each product per week to maximize its profit

Example No. 2 (II)

	Production Time per Batch, hours		
	Product		Production time
Plant	**1**	**2**	**Available hours per week**
1	1	0	4
2	0	2	12
3	3	2	18

Example No. 2 (III)

- Decision variables:
  x_1 = Number of batches of doors produced per week
  x_2 = Number of batches of windows produced per week
- Objective function:
  maximize profit = $5000x_1 + 3000\ x_2$
- Constraints:
  (Plant 1) $x_1 \le 4$
  (Plant 2) $+\ 2x_2 \le 12$
  (Plant 3) $3x_1 + 2x_2 \le 18$
  (Non-negativity) $x_1 \ge 0,\ x_2 \ge 0$

Construction Project Management
(CE 110401346)

7 - Engineering Economic Analysis

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Introduction

- Is any individual project worthwhile?
- Determine whether a proposed solution is financially viable (profitable or not)?
- Given a list of feasible projects, which one is the best?
- What is the best option between competing solutions to a specific problem?
- How does each project rank compared to the others on the list?

7 - 2

Engineering Economic Decision Analysis

- Every decision made costs money (an investment). If these decisions are not made wisely, money will be lost with prospects of bankruptcy
- Economic Analysis considers the economic viability of each and every investment project such that money is made, not lost
- Objective: Strive to secure the highest net dollar return on capital investments which is compatible with the risks incurred

7 - 3

Economic Decision Steps

Problem (Need or Opportunity) Recognition and Definition

↓

Generation of Alternative Solutions

↓

Development of Cash Flows for Feasible Alternative Solutions and Information Gathering

↓

Economic Evaluation of Alternatives

↓

Selection and Implementation of Best Alternative

↓

Post-implementation Analysis and Evaluation

7 - 4

Project Evaluation (Examples)

- Example 1:
  - Housing Project A
  - Construction=10 months
  - Cost = $10,000/month
  - Sale Value=$150,000
  - Total Cost ?
  - Profit ?

  - Housing Project B
  - Construction=20 months
  - Cost=$10,000/month
  - Sale Value=$280,000
  - Total Cost?
  - Profit?
- Example 2: Project requires an investment of $1,000 today and returns $1,100 in one year
  – Is it profitable to make such investment?

7 - 5

Time Value of Money

- Money has a time value
- A dollar received tomorrow in not equivalent to a dollar received today (The money have the same nominal quantity but the dollar does not have the same usefulness or buying power)
- Because of this value differential we cannot estimate benefits or costs simply by adding dollars amount that are realized in different periods

7 - 6

Time Value of Money II

- Not all projects can be described completely in terms of monetary costs and benefits.
  - Social Benefits (e.g. Hospital, School)
  - Intangible Benefits (e.g. new cafeteria to workers)

7 - 7

Discount Rate, Interest Rate, and Minimum Attractive Rate of Return

- Discount Rate:
  - Represents the way money now is worth more than the money later (Investment opportunities + Inflation).
  - Specified as a rate - given as some percentage per year
  - Assumed to be constant over the time

7 - 8

Discount Rate, Interest Rate, and Minimum Attractive Rate of Return II

- Interest Rate:
  - Contractual arrangement between a borrower and a lender
  - discount rate > interest rate
- Minimum Attractive Rate of Return (MARR)
  - Minimum discount rate accepted by a person or organization to accept the risks of a determined project or product

7 - 9

Interest Formulas

- *i* = Effective interest rate per interest period (discount rate or MARR)
- n = Number of compounding periods
- P = Present sum of money
- F = Future sum of money
- A = End-of-period cash flow in a uniform series counting for n periods

7 - 10

Interest Formulas II

- Future Value
  - $FV_1 = 1 \times (1 + i)$
  - FV_1 = Future Value of \$1 at the end of year 1
  - If $i = 10\%$
    - $FV_1 = 1 \times (1 + 0.10) = 1.10$
    - $FV_2 = 1.10 \times (1 + 0.10) = 1.21$
  - FV_2 = Future Value of \$1 at the end of year 2
    - $FV_2 = 1 (1 + i)(1 + i) = 1 (1 + i)^2$
  - In general the future value of \$1 at the end of n years will be: $FV_n = 1 (1 + i)^n$

7 - 11

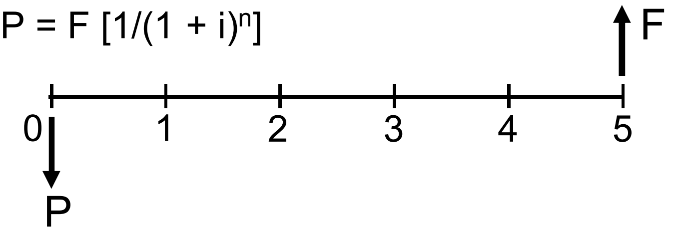
Interest Formulas III

- Inflation of 1% day:
- Not compounding:
  - 1 X 365 = 365%/year ?
  - FV = 1 X (1 + 3.65) = 4.65
- Compounding:
  - $FV = 1 \times (1 + 0.01)^{365}$
  - FV = 37.8 ⟶ 3,680% >>>>> 365 %

7 - 12

Interest Formulas IV

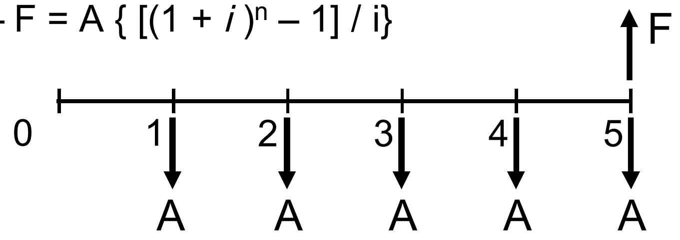
- Single Payment Compound Amount Factor
  - (F/P, i%, n) = $(1 + i)^n$
  - F = P $(1 + i)^n$
- Single Payment Present Worth Factor
  - (P/F, i%, n) = 1/ $[(1 + i)^n]$ = 1/ (F/P, i%, n)
  - P = F $[1/(1 + i)^n]$



7 - 13

Interest Formulas V

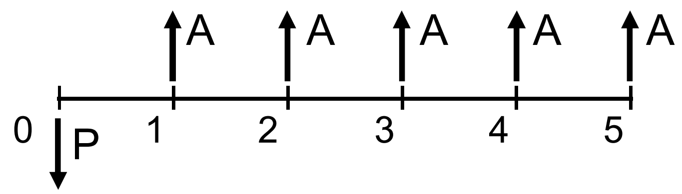
- Uniform Series Sinking Fund Factor
  - (A/F, i%, n) = i / $[(1 + i)^n - 1]$
  - A = F { i / $[(1 + i)^n - 1]$ }
- Uniform Series Compound Amount Factor
  - (F/A, i%, n) = $[(1 + i)^n - 1]$ / i = 1 / (A/F, i%, n)
  - F = A { $[(1 + i)^n - 1]$ / i}



7 - 14

Interest Formulas VI

- Uniform Series Capital Recovery Factor
  - (A/P, i%, n) = [i (1 + i)^n] / [(1 + i)^n – 1]
  - A = P { [i (1 + i)^n] / [(1 + i)^n – 1] }
- Uniform Series Present Worth Factor
  - (P/A, i%, n) = [(1 + i)^n – 1] / [i (1 + i)^n]= 1 / (A/P, i%, n)
  - P = A { [(1 + i)^n – 1] / [i (1 + i)^n] }



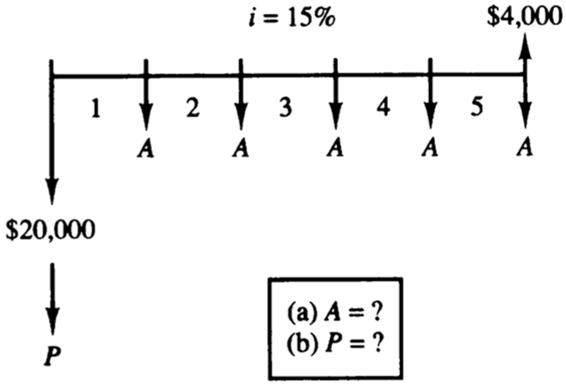
7 - 15

(Example 3)

- $ 20,000 equipment expected to last 5 years
- $ 4,000 salvage value
- Minimum attractive rate of return = 15%
- What are the?
  - A - Annual equivalent
  - B - Present Equivalent

7 - 16

(Example 3) II



7 - 17

(Example 3) III

- P = -$ 20,000 + $ 4,000 (P/F, 15%, 5) = -$ 20,000 + $ 4,000 [1/ $(1.15)^5$] = -$18,011
- A = -$ 20,000 (A/P, 15%, 5) + $ 4,000 (A/F, 15%, 5) = -$ 20,000 { [0.15 $(1.15)^5$] / [$(1.15)^5$ – 1] } + $ 4,000 { 0.15 / [$(1.15)^5$ – 1] } =-$5,373

7 - 18

Comparison of Alternatives

- The first step is to lay out the estimated cash flows → Sequence of benefits (returns) and costs (payments) over time
- Several Evaluation Criteria:
  - Equivalent Worth Methods:
    - Present Worth Method
    - Annual Worth Method
    - Future Worth Method
  - Ratio Methods
  - Internal Rate-of-Return

7 - 19

Comparison of Alternatives II

- Correct selection of the discount rate is fundamental. Its choice can easily change the ranking of projects
  - Example: 2 equipment one needs human operator (initial cost $10,000, annual $4,200 for labor) the second is fully automated (initial cost $18,000, annual $3,000 for power). n=10 years.
  - Is the $8,000 more in the initial investment worth the $1,200 annual savings?

7 - 20

Comparison of Alternatives III

- Net Present Value (i=5%) = -8,000 + 1,200 x [$(1.05)^{10}$ - 1) / (0.05 $(1.05)^{10}$)] = 1,264

i (%)	0	5	10	15	∞
NPV(i%)	4,000	1,264	−632	−1,976	−8,000

- There is a critical value of i that change the equipment choice (around 8.5%)

7 - 21

Equivalent Worth Method

- Coverts all relevant cash flows into equivalent (comparable) amounts at the MARR

7 - 22

Present Worth Method

	Machine	
	A	B
Initial cost	$20,000	$30,000
Life	5 years	10 years
Salvage value	$4,000	0
Annual receipts	$10,000	$14,000
Annual disbursements	$4,400	$8,600

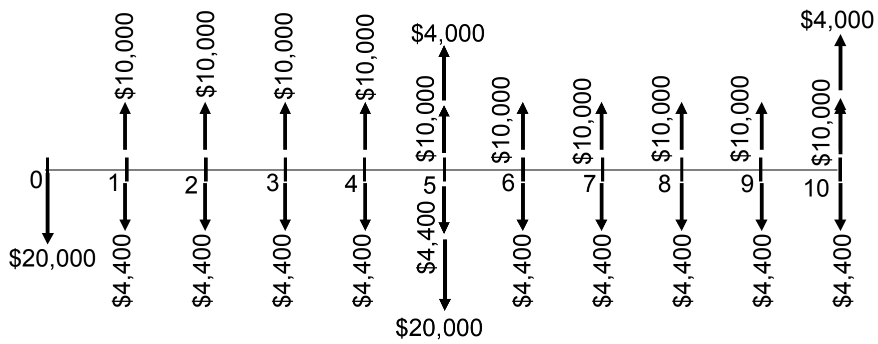
Minimum attractive rate of return = 15%

Assume 10-year study period and repeatability

7 - 23

Present Worth Method

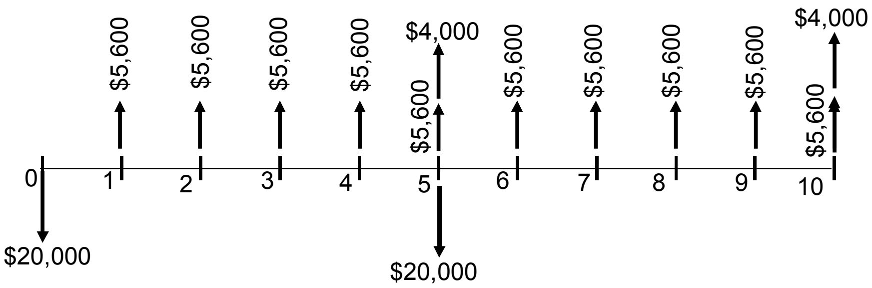
- Machine A



7 - 24

Present Worth Method

- Machine A

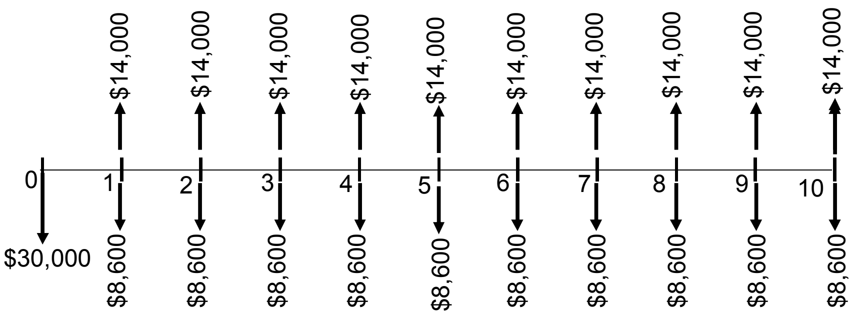


- NPV = -\$20,000 + -\$20,000 (P/F, 15%,5) + \$4,000 (P/F, 15%,5) + \$4,000 (P/F, 15%,10) + \$5,600 (P/A, 15%,10) = \$1,139

7 - 25

Present Worth Method

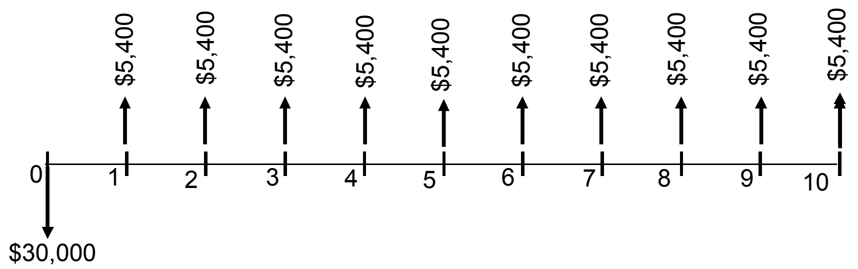
- Machine B



7 - 26

Present Worth Method

- Machine B



- NPV = -$30,000 + $5,400 (P/A, 15%,10) = -$2,899

7 - 27

Equivalent Worth Methods

- Only provides a good comparison between projects when they are strictly comparable in terms of investment or total budget
- Focus attention on quantity of money
- Net present value is different than profit (discount rate X interest rate)
- Give no indication of the scale of effort required to achieve the result

7 - 28

Internal Rate of Return Method (IRR)

- Involves the calculation of the interest rate that is compared against a minimum standard of desirability (MARR).
- It is the interest rate for which the Net Present Value of the project is ZERO (PV of inflow = PV of outflow)
- Eliminates the need to find a proper MARR
- Rankings cannot be manipulated by the choice of MARR

7 - 29

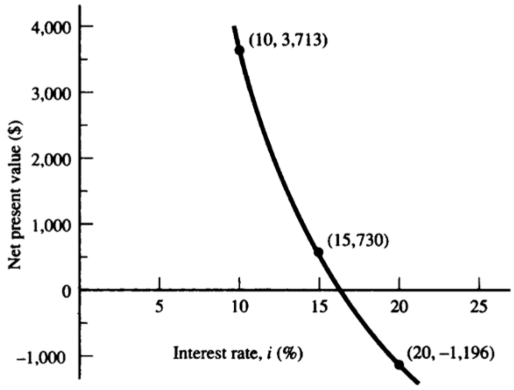
Internal Rate of Return Method (IRR) II

	Machine A
Initial cost	$20,000
Life	5 years
Salvage value	$4,000
Annual receipts	$10,000
Annual disbursements	$4,400

- 0(i%) = -20,000 + 5,600 (P/A, i%, 5) + 4,000 (P/F, i%, 5)
- I = +- 16.9% > 15% then the project is justified

7 - 30

Internal Rate of Return Method (IRR) III



7 - 31

Internal Rate of Return Method (IRR) III

	B
Initial cost	$30,000
Life	10 years
Salvage value	0
Annual receipts	$14,000
Annual disbursements	$8,600

- 0(i%) = -30,000 + 5,400 (P/A, i%, 10)
- = +- 12.5% < 15% then the project is not justified

7 - 32

Continuous Compounding and Discounting

- Variety of interest rates offered on deposits, banking, saving and loan associations
  - Semi-annually
  - Quarterly
  - Daily
- **The greater the frequency with which the interest is compounded, the higher the future value of the deposit**

7 - 33

Continuous Compounding and Discounting II

- Example:
  - Deposit $100 in a bank for one year at an annual rate of 6%
    - 100 (1+0.06) = $106.00
  - Compounded twice a year
    - 100 (1+0.06/2)(1+0.06/2) = $ 106.10
- The higher the interest rate and the longer the duration, the greater is the impact of the compounding method

7 - 34

Nominal Interest Rate of Return

- r = the nominal interest rate per year
- M = the compounding frequency or the number of interest periods per year
- r/M = interest rate per compounding period
- Effective interest rate = the rate that truly represents the amount of interest earned in a year or some other time period
- $i_{effective} = (1 + r/M)^M - 1$
- $i_{effective}$ = effective annual interest rate

7 - 35

Example

- If a savings bank pays 1 ½% interest every three months, what are the nominal and effective interest rates per year?
- Nominal %/year, r = 1 1/2% x 4 = 6%
- Effective interest rate per year,
  - $i_{effective} = (1 + 0.06/4)^4 - 1 = 0.061 = 6.1\%$
- Notice that when M=1, $i_{effective} = r$

7 - 36

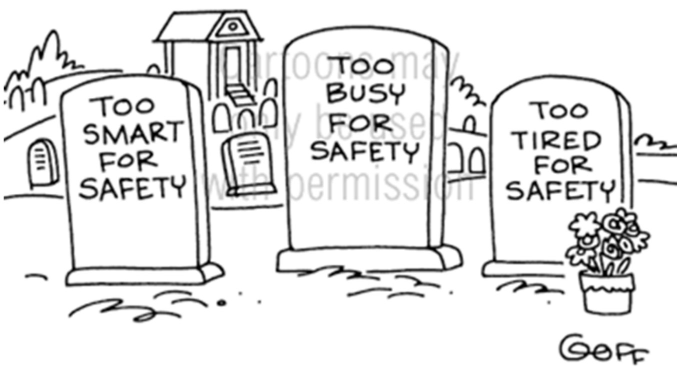
The Hashemite University

Construction Project Management
(CE 110401346)

8 – Managing Construction Safety

Dr. Khaled Hyari
Department of Civil Engineering
Hashemite University

Construction Safety



Construction Safety

"We were just passing by. Did you have any workers today who thought safety was a waste of time?"

8 - 3

Construction Safety

- What?
  - A Dictionary Definition: The quality or condition of being safe; freedom from danger, injury, or damage; security

8 - 4

Construction Safety

- In the United States
  - Construction consists 5% of the U.S. workforce, and accounts for 20% of the work fatalities and 12% of disabling injuries
  - The estimated total cost (direct and indirect) of construction accidents exceed 17 billions dollars
  - "Construction site accidents *kill and injure hundreds of thousands of workers each year.* Indeed, working at a construction site is one of the most dangerous occupations in the United States. ……"
    (www.construction-injuries.com)

8 - 5

Motivation for Safety

- Moral responsibility
- Financial consequences
- Schedule impacts
- Quality of Work
- Market response
- Others

8 - 6

Financial Consequences for Safety

- Poor safety record results in:
  - Increased worker's compensation insurance premiums
  - Increased public liability
  - Increased costs due to lost project time
- A construction firm can lose its competitive edge because of the increased insurance premiums as a result of poor safety

8 - 7

OSHA

- Occupational Safety and Health Administration
- The concern over the frequency and extent of industrial accidents and health hazards led to the passage of Occupational Safety and Health Act of 1970
- The essence of OSHA Act is that every worker should be provided with a safe place to work

8 - 8

OSHA II

- Each employer shall:
  1. Furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or likely to cause death or serious physical harm to his employees
  2. Comply with occupational safety and health standards
- Virtually, every business is affected by OSHA regulations (not construction only)

OSHA III

- OSHA is responsible for developing and enforcing safety regulations:
  - Developing standards
  - Inspecting workplaces to enforce compliance
  - Performing short-term training and education
  - Developing injury and illness statistics

OSHA IV

- To do that, OSHA has produced a comprehensive set of:
  - Safety and health regulations
  - Inspection procedures
  - Record keeping requirements where employers are required to keep records of all work related deaths, injuries, and illnesses

OSHA V

- 1926.20 Ssubpart C: General Safety & Health Provisions

(a) Contractor requirements.

(a)(1) Section 107 of the Act requires ….. that no contractor or subcontractor for any part of the contract work shall require any laborer or mechanic employed in the performance of the contract to work in surroundings or under working conditions which are unsanitary, hazardous, or dangerous to his health or safety.

OSHA VI

(b) Accident prevention responsibilities.

(b)(1) It shall be the responsibility of the employer to initiate and maintain such programs as may be necessary to comply with this part.

(b)(2) Such programs shall provide for frequent and regular inspections of the job sites, materials, and equipment to be made by competent persons designated by the employers.

OSHA VII

- Consider three elements in a working definition of “construction safety”
  - A person will not be required to work in surroundings or conditions which are unsafe or dangerous to health
  - Employer is responsible for initiating and maintaining a safety/health program that complies with standards
  - Each individual is responsible for complying with applicable safety requirements

OSHA VIII

1926.16 RULES OF CONSTRUCTION
SUBPART B GENERAL INTERPRETATIONS

(a)"…In no case shall the prime contractor be relieved of overall responsibility for compliance with the requirements of this part for all work to be performed under the contract."

(b) "By contracting for full performance of a contract … the prime contractor assumes all obligations prescribed as employer obligations under the standards contained in this part, whether or not he subcontracts any part of the work.

8 - 15

OSHA IX

(c) "… subcontractor of any stage … also assumes responsibility for complying with the standards in this part with respect to that part. Thus, the prime contractor assumes the entire responsibility under the contract and the subcontractor assumes responsibility with respect to his portion of the work. With respect to subcontracted work, the prime contractor and any subcontractor or subcontractors shall be deemed to have joint responsibility.

(d) Where joint responsibility exists, both the prime contractor and his subcontractor or subcontractors, regardless of tier, shall be considered subject to the enforcement provisions of the Act.

8 - 16

OSHA Inspections

- OSHA makes inspections of work sites to check the level of compliance with regulations
- Inspections can be made under 3 criteria:
  - Random or scheduled inspections
  - Reports of major accidents
  - Employee complaints
- Inspections are made by OSHA compliance officers

OSHA Fines and Penalties

- There are established penalties for violations of OSHA regulations
- Not all violations bring fines, but all unsafe conditions must be corrected
- The correction of unsafe conditions must occur within a designated period
- Failure to correct a violation will probably result in additional fine

OSHA Fines and Penalties II

- If the unsafe condition is serious, the fine may be quite high, up to $7000 for each day it remains uncorrected
- If a situation is considered one of “imminent danger”, it must be corrected immediately, with a shutdown of the operation until the correction has occurred
- “Imminent danger” is a situation that could reasonably be expected to cause death or serious physical harm

OSHA Fines and Penalties III

- After an OSHA inspection, the employer is notified with any violations and the corresponding penalty
- The employer has 15 days to contest any of the allegations or penalties
- In recent years, OSHA has become more aggressive in posing penalties for non compliance
- Fines of more than $1 million have been imposed against some employers!

OSHA Fines and Penalties IV

NEW JERSEY ASSEMBLY BILL A-2355

- "AN ACT concerning the safety record of bidders competing for state-funded construction contracts …."
  - No contract shall be awarded to a bidder …
    - Has been assessed a penalty by the federal OSHA
    - Has been assessed a penalty by any state for willful or repeated violations
  - Bidder shall submit a written certification indicating it does not have a history of violations
  - Successful bidder shall not employ any subcontractor if that subcontractor has a history of violations

8 - 21

Voluntary Protection Program (VPP)

- OSHA initiated the VPP program to increase its effectiveness in reducing worker injuries
- The program is designed to recognize outstanding achievement of firms that have successfully incorporated comprehensive safety and health programs in their overall management system
- Firms can be designated as:
  - Star, Merit, or Demonstration

8 - 22

Voluntary Protection Program (VPP) II

- The VPP designation is granted when a firm has established a cooperative relationships with its employees and OSHA
- The benefits of the program have shown that participants regularly experience injury rates that are 60% -80% below the industry average
- Employers who participate in this program are not scheduled for OSHA programmed inspections

8 - 23

Management Responsibility

- Under OSHA requirements, only management may be penalized for safety violations
- So, employees are not penalized for violating OSHA requirements; management is held responsible

8 - 24

Management Responsibility

- Employer's Safety & Health Program (OSHA)
  - Management Commitment & Leadership
  - Assignment of Responsibility
  - Identification & Control of Hazards
  - Training & Education
  - Record Keeping & Hazard Analysis
  - First Aid & Medical Assistance

8 - 25

Construction Accidents

- Most serious accidents involve:
  - Construction equipment operations
  - Trench and embankment failure
  - Falls from elevated positions
  - Collapse of temporary structures and formwork
  - Failure of structures under construction

8 - 26

Safety Performance Measures

- OSHA recordable incidence rate
- Experience Modification Rating (EMR)

8 - 27

OSHA Recordable Incidence Rate

- OSHA recordable incidence rate: Employers are required to record and report the following information:
  - Number of fatalities
  - Number of injuries and illnesses involving lost workdays
  - Number of injuries and illnesses involving restricted workdays
  - Number of days away from work
  - Number of days of restricted work activity
  - Number of injuries and illnesses without lost workdays

8 - 28

OSHA Recordable Incidence Rate II

- OSHA incidence rate is calculated as follows:
- Incidence rate = No. of incidents * 200,000 hours / No. of hours worked
- The number of incidents in the formula is the total of the numbers of fatalities, injuries and illnesses involving lost and restricted workdays, and injuries and illness without lost workdays
- The 200,000 hours in the formula represents the equivalent of 100 employees working 40 hours per week, 50 weeks per year, and is the standard base of incidence rates

8 - 29

OSHA Recordable Incidence Rate III

- OSHA recordable incidence rate average: The US construction industry average for the recordable incidence rate is 12.5

8- 30

Experience Modification Rating (EMR)

- EMRs are established by independent rating bureaus (basically insurance companies)
- These companies gather safety information about contractors
  - Accidents, safety programs, top management commitment, etc.
- Based on these gathered information, they calculate an EMR for each contractor

8 - 31

Experience Modification Rating (EMR) II

- EMR dictates the contractor's premium of the workers' compensation insurance
  - Higher EMR values mean that the contractor pays more money to buy insurance for his workers
  - Similar to buying insurance for your car
- EMR values range between 0.5 and 2.0
- An EMR of 1.0 means an employer has an average safety record
- An EMR of 1.2 means that a contractor pays 20% more for workers' compensation insurance than a similar company with an EMR of 1.0
- An EMR of less than 1.0 indicates that the contractor is experiencing fewer losses than other comparable companies

8 - 32

Safety Programs

- All construction firms need a carefully planned and directed safety program to:
  - Minimize accidents
  - Ensure compliance with safety regulations
- No safety program will be successful without the support of top management
- Job site supervisors have traditionally neglected safety in their haste to get the job done on time and within budget
- Construction supervisors need to be convinced that safety is as important as production
- An effective safety program must install a sense of safety consciousness in every employee

8 - 33

Safety Programs II

Major elements of a comprehensive safety program

1. A formal safety training program for all new employees
2. Periodic refresher training for each worker
3. Formal supervisory safety training program for all supervisors
4. A program of regular site visits by safety personnel to review and control job hazards
5. Provision of adequate personal protective equipment, first-aid equipment, and trained emergency personnel
6. An established procedure for the emergency evacuation of injured workers
7. Provisions for maintaining safety records and reporting accidents in compliance with OSHA requirements

8 - 34

Safety Procedures

- Most serious construction accidents involve:
  - Construction equipment operations
  - Trench and embankment failure
  - Falls from elevated positions
  - Collapse of temporary structures and formwork
  - Failures of structures under construction
- Therefore, special management attention should be devoted to the safety of these activities

8 - 35

Safety Procedures II

- Good housekeeping on a project site is both a safety measure and an indicator of good project supervision. Used formwork and other material lying around a work area increase the likelihood of accidents

8 - 36

Safety Procedures III

- Equipment Operations:
  - Utilize guides or signalpersons when the operator's visibility is limited or when there is danger to nearby workers. Backup alarms must be used when equipment operates in reserve
  - Use care when operating equipment on side slopes to prevent overturning
  - Do not allow workers to ride on equipment unless proper seating is provided
  - Exercise extreme caution and comply with safety regulations when operating near high-voltage lines
  - Make sure that machines are equipped with required safety features and that operators use safety belts

8 - 37

Safety Procedures IV

- Equipment Operations, Continued:
  - Do not exceed safe load limits when operating cranes (considering operating radius and boom position)
  - Park equipment with the brake set, blade or bowl grounded, and ignition key removed at the end of work
  - When hauling heavy or oversized loads on highways, make sure that loads are properly secured and covered if necessary. Slow-moving and oversized vehicles must use required markings and signals to warn other traffic

8 - 38

Safety Procedures V

- Excavations
  - The side of excavations must be properly shored or sloped to the angle of repose to prevent cave-ins.
    - Banks over 1.5 meters must be shored, cut back to a stable slope, or otherwise protected (OSHA regulations)
    - Protective systems (sloping, benching, shoring, or shielding) for excavations over 6.1 m deep must be designed by a registered professional engineer (OSHA regulations)
  - Ensure that workers are not allowed under loads being handled by excavators or hoists
  - Watch out for buried lines and containers when excavating

Safety Procedures V

- Excavations, Continued
  - Avoid the operation of equipment near the top edge of an excavation because this increases the chance of slope failure. The storage of materials near the top edge of an excavation, vibration, and the presence of water also increase the chance of slope failure
  - If workers are required to enter the excavation, no spoil or other material may be stored within 0.6 m of the edge of the excavation

Safety Procedures VI

- Construction of Structures:
  - Properly guard all openings above ground level
  - Provide guard rails, safety lines, safety belts, and/or safety net for workers on scaffolds or steel work
  - Ensure that temporary structures are properly designed and constructed
  - Special caution should be exercised in high-rise concrete construction.
    - Forms must be of adequate strength and properly braced
    - Rate of pour must be maintained at or below design limits
    - Shoring must be adequately braced and not removed until the concrete has developed the required strength

8 - 41

Environmental Health in Construction

- Major environmental health problems encountered in construction
  - Noise
  - Dust
  - Radiation
  - Toxic materials
  - Heat and cold

8- 42

Noise

- Permissible noise levels are a function of length of exposure and range from 90 decibels for 8-h exposure to 140 decibels for impact noise
- Personal ear protection must be provided when satisfactory noise level cannot be attained by engineering control
- Increasing use of cab enclosures on construction equipment to protect equipment operators from equipment noise
  - Improved operator environment
  - Safety hazard as it is difficult for workers to communicate with the equipment operator
  - Increased attention must be given to the use of backup alarms, hand signals to avoid accidents

8 - 43

Dust

- Safety hazard due to loss of visibility
- Responsible for a number of lung diseases
- Silica dust and asbestos are particularly dangerous
  - Asbestos dust has been found to be a cancer-producing agent

8 - 44

Toxic Materials

- The most frequent hazard consists of buried utility lines and underground gases
- The air in the work area should be tested whenever an oxygen deficiency or toxic gas is likely to be encountered
- Emergency rescue equipment such as breathing equipment should be provided whenever adverse atmospheric (breathing) conditions may be encountered

8 - 45

Radiation

- Ionizing radiation is produced by X-ray equipment and radioactive material
  - X-raying welds
  - Measuring soil density
  - Performing nondestructive materials testing
- Nonionizing radiation is produced by laser equipment, and electronic microwave equipment
  - Laser equipment is widely used for surveying and for alignment of pipelines, tunnels, and structural members

8 - 46

Heat

- Human body acclimate itself to high temperature conditions within a period of 7-10 days
- Serious heat illness may result when workers are not properly acclimated
  - Ranges from fatal heat stroke to minor heat fatigue
  - Heat cramp result when the body's salt level drops too low
- Methods for reducing heat effect on workers include:
  - Use of mechanical equipment to reduce physical labor requirements
  - Scheduling hot work for cooler part of the day
  - Use of sun shields
  - Providing cool rest areas
  - Providing water and salt supply easily accessible to workers
  - Use of proper hot weather clothing

8 - 47

Cold

- Human body will acclimate itself to cold as it will to heat but acclimation period for cold is much longer
- Medical effects of cold include:
  - Frostbite
  - General hypothermia: reduction of the core body temperature (fatal when the body core temperature drops below 18c)
- The major requirement for successful cold-weather construction is the provision of adequate clothing and warming areas
- The use of bulky cold-weather clothing reduces manual dexterity and may increase the possibility of accidents

8 - 48

Construction Project Management
(CE 110401346)

9. Project Quality Management- Introduction

Dr. Khaled Hyari
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Content

- Quality: What? (The concept of quality)
- Quality Why?
- Quality vs. Grade
- Precision vs. Accuracy
- The Management of Quality
- Quality Cost
- Quality Vocabulary
- Quality Hierarchy
- Quality Standards
- Six Sigma

Quality: What? I

- The word ‘quality’ usually carries inferences of excellence or high social status
- Quality in Engineering Sense conveys the concepts of:
  - Conformance to requirements
  - Value for money
  - Fitness for purpose
  - Customer satisfaction

Quality: What? II

- **Quality:** The totality of features and characteristics of a product or service that bear upon its ability to satisfy stated or implied needs
  - What is meant by the word ‘needs’?
  - Product or Service

Quality: What? III

- **Needs:**
  - In a contractual environment, needs are specified, whereas in other environments, implied needs should be identified and defined.
  - In many instances, needs can change with time; this implies periodic revision of specifications.
  - Needs are usually translated into features and characteristics with specified criteria. Needs may include aspects of usability, safety, availability, reliability, maintainability, economics and environment.'

9 - 5

Quality: What? IV

- The definition of quality relates to 'products and services'.
  - Quality systems therefore are not confined to processes where there is a tangible end-product.
    - The product of a garbage disposal organization is well swept streets and empty bins.
    - The product of a management consultant is sound advice
    - The product of a flight attendant is service with a smile

9 - 6

Quality: What? V

- Quality means:
  - Freedom from deficiencies ➔ *reduce costs*
  - ‘doing it right the first time’
  - Client satisfaction ➔ *repeat business*
  - Satisfaction of all employees (all project/organization stakeholders)
  - Continously improving performance ➔ *staying competitive*

Quality: Why? I

- Success of competitors who take quality seriously
- Quality differentiates companies from the competition
- Rising expectations of customers: Clients/owners beginning to demand improved service quality, faster buildings and innovations in technology.
- Clients demand more and more often pre-qualification
- Clients demand adoption of the ISO 9000 standards

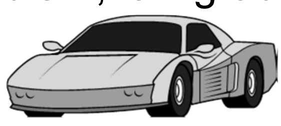
Quality: Why? II

- Growing evidence that growth in market share comes from sustained quality.
- High cost of catastrophic failure
- Inspection is poor substitute for right first time
- The need to promote and control quality is of fundamental importance to any enterprise. Only by providing consistent value for money to their customers can companies hope to generate steady profits for their shareholders and ensure secure livelihoods for their employees

9 - 9

Quality vs. Grade

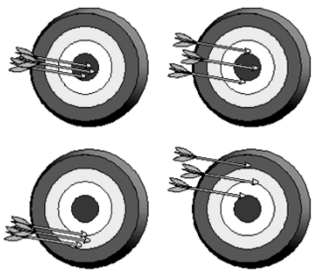
- **Quality**
  - The totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs. Conformance to requirements or specifications.
- **Grade**
  - A category or rank given to entities having the same functional use, but different technical characteristics
- Low quality is always a problem; low grade may not be



9 - 10

Precision vs. Accuracy

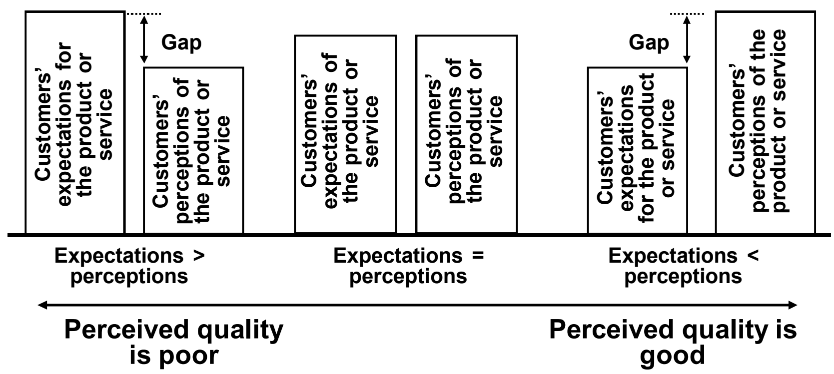
- **Precision:** Consistency that the value of repeated measurements are clustered and have little scatter
- **Accuracy:** Correctness that the measured value is very close to the true value



9 - 11

Perception of Quality

- Perceived quality is governed by the gap between customers' expectations and their perceptions of the product or service



9 -12

The Management of Quality I

- After the Second World War, Japan invited foreign experts to provide advice on how to regenerate their industries. Among them were two Americans, J.M.Juran and W.E.Deming
- Juran and Deming brought a new message which can be summarized as follows:
  – The management of quality is crucial to company survival and merits the personal attention and commitment of top management
  – The primary responsibility for quality must lie with those doing the work. Control by inspection is of limited value

The Management of Quality II

- Juran and Deming brought a new message which can be summarized as follows:
  – To enable production departments to accept responsibility for quality, management must establish systems for the control and verification of work, and must educate and train the work force in their application
  – The costs of education and training for quality, and any other costs which might be incurred, will be repaid many times over by greater output, less waste, a better quality product and higher profits

The Management of Quality III

- Deming's Chain Reaction

Improve Quality ↘

Cost decreases because of less rework, fewer mistakes, fewer delays, snags, better use of machine time and materials ↓

Productivity improves ↙

Capture the market with better quality and lower price ↑

Stay in business ↗

Provide jobs and more jobs ↗

9 - 15

The Management of Quality III

- America's Response:
  - Initially US stick to its assumption that Japanese success was price related and responded with strategies aimed at reducing domestic production costs and restricting imports. This did not prove beneficial
  - By the end of the 1970's US reached a major quality crisis.
  - They started to think "if Japan can.. Why can't we?
  - CEO of top US organizations then took an initiative

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Quality Costs I

- Cost of conformance – cost of the company's quality efforts
  - Appraisal cost
  - Prevention cost
- Cost of non-conformance
  - Internal failures
  - External failures

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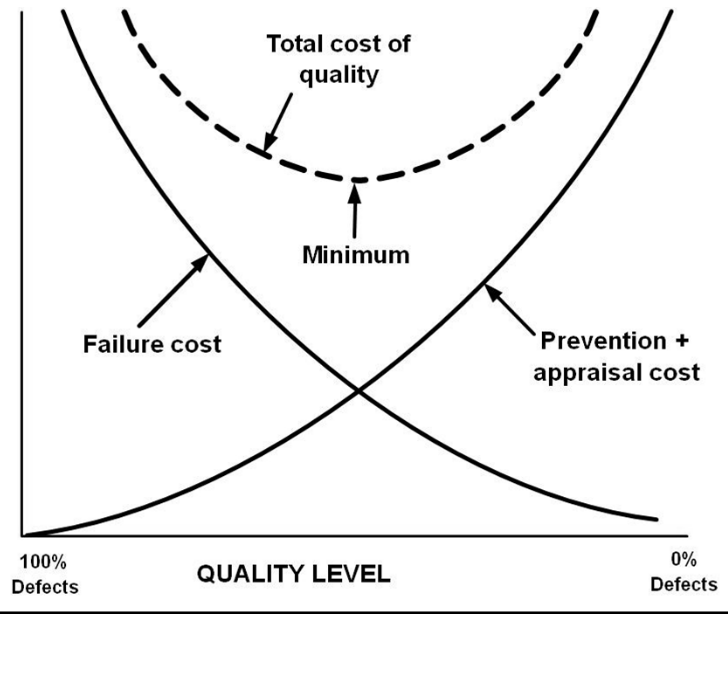
Quality Costs II



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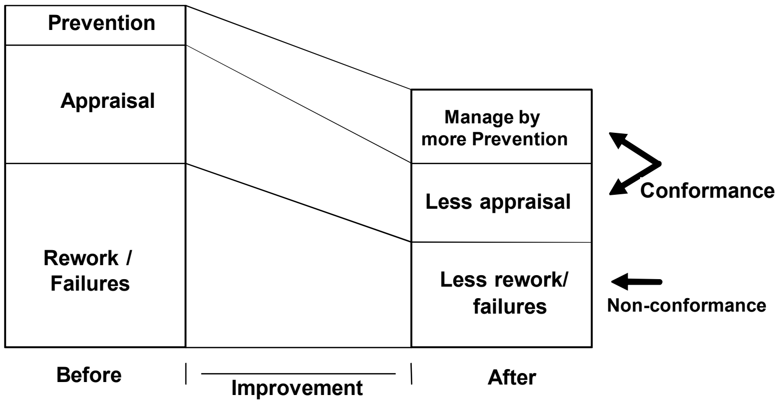
Quality Costs: Why? I

- To quantify quality problems
- To speak the ‘money language’ to managers
- To support a quality improvement program



9 - 19

Cost of Non-conformance

- Contractors pay a significant price for poor quality resulting from accidents, waste, rework, inefficiencies, poor subcontractor performance and poor communication
  - These costs are estimated to be between 5% and 30% of the construction cost of a facility
- In addition there are intangible ‘hidden’ costs such as lost sales due to low customer loyalty

9 - 20

Cost of Conformance

- Administration of the quality management program
- Quality staff salaries
- Training costs
- Inspection of direct hire and subcontractor work
- Inspection at vendor source of supply
- Inspection of shipments
- Review of shop drawings
- Meetings of the steering committee and quality improvement teams

Quality Vocabulary I

- **Quality policy:** The overall quality intentions and directions, of an organization as regards quality, as formally expressed by top management
- **Quality management:** That aspect of the overall management function that determines and implements the quality policy
- **Quality system:** The organizational structure, responsibilities, procedures, processes and resources for implementing quality management

Quality Vocabulary II

- Quality ***management*** includes all the actions an organization takes to achieve its quality ***policy***.
- These actions may be :
  - Unplanned and unsystematic, perhaps in reacting to events as they unfold (some of the actions)
  - Planned and follow organized routines and procedures established in advance. (most of the actions) ⇨ The quality ***system***

9 - 23

Quality Vocabulary III

- **Quality system** The organizational structure, responsibilities, procedures, processes and resources for implementing quality management
- **Quality assurance** All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality
- **Quality control** The operational techniques and activities that are used to fulfill requirements for quality

9 - 24

Quality Vocabulary IV

- Quality system is made up of a number of elements and these elements are identified and described in quality system standards.
  - Some of these elements will provide ***quality control*** by eliminating non-conformance.
  - Others will supply verification, or ***assurance,*** that standards have been met—an assurance which may be made available to management, to the customer, to regulatory authorities, or to all three

9 - 25

Quality Systems

- A quality system prescribes processes, not product or technical details
- The system is controlled through a documentation hierarchy
- A quality system specifies how something has to be done, then verify it has been achieved
- The purpose is to ensure every time a process is performed, the same information, methods, skills and controls are used in a consistent manner

9 - 26

Quality Policy

- Objectives of an organization **Quality policy:**
  - The organization should achieve and sustain the quality of the product or service produced so as to meet continually the purchaser's stated or implied needs.
  - The organization should provide confidence to its own management that the intended quality is being achieved and sustained.
  - The organization should provide confidence to the purchaser that the intended quality is being, or will be, achieved in the delivered product or service provided. When contractually required, this provision of confidence may involve agreed demonstration requirements.'

QC vs. QA

- **Quality Control (QC):** A set of activities or techniques whose purpose is to ensure that all quality requirements are being met by monitoring of processes and solving performance problems
  - Monitoring work results
  - Inspections and tests
- **Quality Assurance (QA):** A set of activities or techniques whose purpose is to demonstrate that quality requirements are met. QA should give confidence that quality requirements are being met
  - Prepare quality plans
  - Audits
  - Training

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Project Management Context

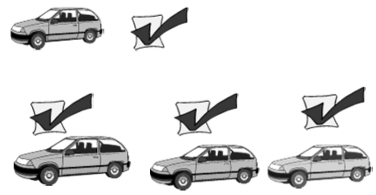
- **Quality Control (QC):** Monitoring specific project results to determine if they comply with relevant quality standards, and identifying ways to eliminate causes of unsatisfactory results.
- **Quality Assurance (QA):** The application of planned, systematic quality activities to ensure that the project will employ all processes needed to meet requirements

Quality of Processes

Quality of product

↑

Quality of processes



- To achieve quality *consistently*, we cannot rely on quality control (QC)
  - We must 'build in' quality in the production process
- This can be achieved through Quality Assurance (QA)
  - QA is about *decreasing cost that occur due to checking of work and expensive remedial works*

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Prevention vs. Inspection

- ***Prevention over Inspection:*** Many years ago, the main focus of quality was on inspection. The cost of doing so is so high that it is better to spend money on preventing problems. "Quality must be planned in not inspected in."
- One of the fundamental tents of modern quality management is: Quality is planned, designed, and built in – not inspected

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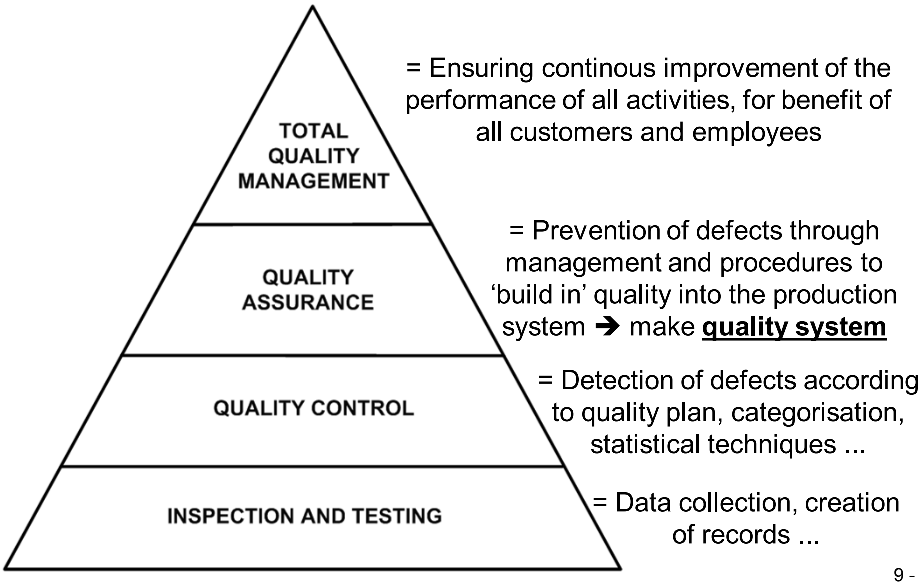
Quality Hierarchy



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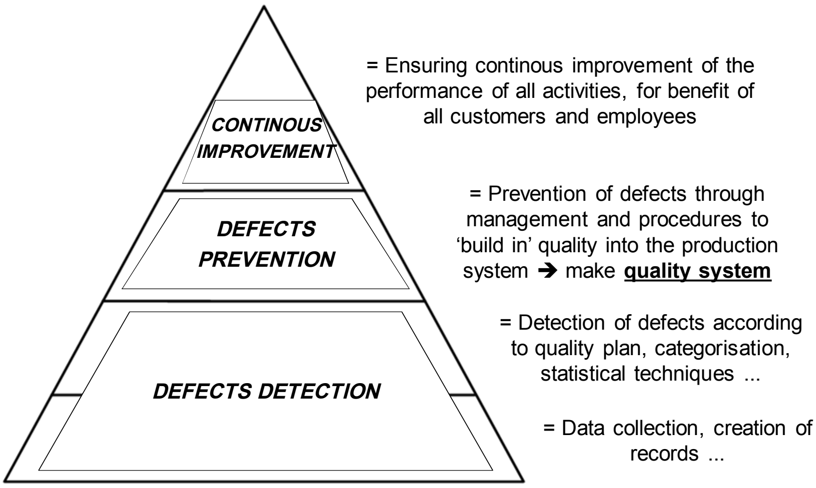
Quality Hierarchy



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ISO 9001

- BS5750 Quality Management first introduced in Britain in 1979
- IS0 (the International Organization for Standardization) is a worldwide federation of national standards bodies (IS0 member bodies).
- Adopted by the International Standards Organisation (ISO) in Geneva and was reborn as ISO 9000 Quality Management and Quality Assurance Standards in 1987
- Updated in 1994, 2000, and 2008

ISO International Organization for Standardization

ISO 9001

- **ISO 9000:2005: Quality management systems — Fundamentals and vocabulary**
- **ISO 9001:2008: Quality management systems — Requirements**
- **ISO 9004:2000: Quality management systems — Guidelines for performance improvements**
- **ISO 10005:2005: Quality management systems — Guidelines for quality plans**
- **ISO 10006:2003: Quality management systems — Guidelines for quality management in projects**

ISO 9001

- NOT a quality award
- A model/framework for documented quality management
- Compliance with ISO 9001 is certified by various institutes. This is called certification or registration
- A process standard, NOT a product standard
  - i.e. applies to any industry
  - The requirements for quality management system are the same for an engineering organization as for a contractor
  - The difference is how each requirement is applied to each distinct business process

9 - 37

Six Sigma I

- Six Sigma means a failure rate of 3.4 parts per million or 99.9997% perfect
- Six sigma: A rigorous analytical process for anticipating and solving problems:
- It is essentially based on three underlying facts:
  - You can manage what you measure
  - You can measure what you can define
  - You can define what you understand.

9 - 38

Six Sigma II

- The objective of six sigma is to improve profits through variability and defect reduction, yield improvement, improved consumer satisfaction and best-in-class product / process performance.
- 3 or 6 sigma – represents level of quality
  - +/- 1 sigma equal to 68.26%
  - +/- 2 sigma equal to 95.46%
  - +/- 3 sigma equal to 99.73%
  - +/- 6 sigma equal to 99.99%