Turn off your cell phone!

Turn in your homework!

Construction Planning and Scheduling

CIEG125 - Introduction to Civil Engineering

Lecture 11

Fall 2005

10/22/05

- Ethics presentations – groups 16, 17, 18 and 19.
- Construction
  - The construction industry
  - Estimating
  - Scheduling
- Project 3
- Homework 8

Outline

- The Construction Industry
- Major Types of Construction
- The Project Life Cycle
- Professional Services Available to Owner
- Construction Contractors
- What does a Construction Manager (CM) do?

Construction Industry

- A conglomeration of diverse fields and participants
- A sector of the economy (~9% of GNP)
- Products provide foundation for industry
  - office buildings and manufacturing facilities
  - infrastructure (highways, bridges, dams etc)
  - power plants

Construction Activity

- 85% is contract construction (i.e., done by one firm for another under contract)
- 1 million US construction contractors
- 60% of contracting by top 400 contractors, such as:
  - Brown and Root
  - M. W. Kellogg
  - Bechtel

Major Types of Construction

- Residential Housing
- Institutional and Commercial Buildings
  - high-rise office buildings and hotels
  - sports stadiums, hospitals, shopping centers
- Specialized Industrial Construction
  - coal-fired or nuclear power plants
  - oil refineries, steel mills, chemical processing plants
- Infrastructure and Heavy Construction
  - highways, tunnels, bridges, dams
  - pipelines, sewage treatment plants

Project Life Cycle

- Market Demands or Perceived Needs
  - definition of project objectives and scope
  - e.g., 500,000 sq. ft. of office space
- Conceptual Planning/Feasibility Studies
  - Preliminary design
  - Economic feasibility
- Design and Engineering
  - Construction Plans and Specifications

Project Life Cycle

- Procurement and Construction
  - Constructed Facility
- Startup for Occupancy
  - Occupancy Permit Issued
  - Acceptance of Facility
- Operation and Maintenance
  - Facility is used and maintained
  - Facility is renovated
- Disposal of Facility
  - Facility is demolished and possibly recycled

Professional Services Available to Owner

- Financial Planning Consultants (CPAs)
- Investment Bankers
- Architectural/Engineering (A/E) Firm
  - develop preliminary design
  - owner gets contractor bids on design
  - A/E firm completes detailed design & inspects
  - A/E firm acts on behalf of owner (changing)
- Design/Construct Firms
  - integrates design & construction processes

Professional Services Available to Owner

- Professional Construction Managers
  - manage the entire construction process for an owner
  - offer professional services (e.g., design, inspection, management) from inception to completion of the construction project
- Operation and Maintenance Managers
- Facility Managers
  - compile computer records of building plans
  - maintain space inventories and conditions
  - maintain furniture and equipment inventories

Construction Contractors

- General Contractors (GC)
  - coordinates all tasks in a construction project
  - contracts with subcontractors
  - could be replaced by construction management firm
  - knowledgeable about local labor force
- Specialty Contractors (“Subs”)
  - mechanical, electrical, foundation, excavation
- Material and Equipment Suppliers
  - steel fabrication and erection
  - ready-mixed concrete delivery
  - roofing and glazing

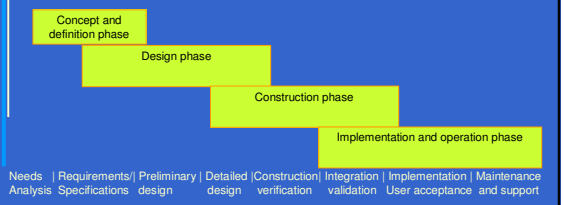
What does a CM do?

- A CM manages a construction project
- Strive for efficient utilization of labor, material and equipment
- Some of the activities of CM
  - break down work into work packages
  - estimate durations and costs of work packages
  - create schedule when work packages are to be done and when needed materials are to be procured
  - contract the work to subs
  - monitor schedule and costs of work packages

The Importance of Construction Management

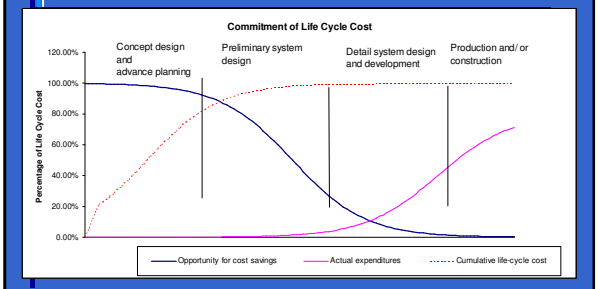
- Construction is a critical building block in the project life cycle
- Construction represents a commitment to life cycle cost
- Construction represents the largest part of visible costs

Construction as the building block…..



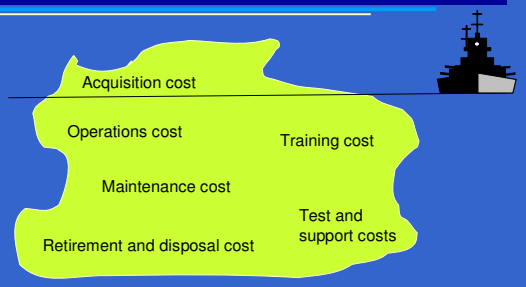
Source: Engineering Economy, Blank, Tarquin, McGraw Hill, 1989.

Commitment to life-cycle cost



Source: Blanchard, Fabrycky, Systems Engineering and Analysis, Prentice Hall, 1981

Visible costs...



Types of contracts

- Lump sum
- Unit price
- Guaranteed maximum fixed price
- Cost reimbursable
- Construction management
- Design construct
- ……BOT, DBOT….

Contract provisions

- Bonding
- Insurance and indemification
- Changed conditions
- Change orders
- Schedules, delays, liquidated damages, bonuses and penalties
- Payment terms and retainage
- Subcontracting
- Alternate dispute resolution
- Partnering

Construction Company Organization

- Main office
  - operations
  - engineering and estimating
  - administration
  - other
    - legal
    - employee relations
    - business development
    - public relations
- Project staff
  - project manager
  - project engineer
  - general superintendent
  - office manager

Responsibilities

- Coordination with designer
  - constructability
  - value engineering
- Temporary structures
- Inspection and quality control
- Shop drawings
- Estimating and bidding
- Scheduling
- Cost control

Summary

- Construction industry is a very large and fragmented industry.
- There are many “players”
- Owners buy construction
- A/E firms design it
- Contractors: GC and subs build it
- CM firm might manage the construction process instead of a GC

Outline Estimating

- Introduction
- Labor, Material and Equipment
- Cost Estimating Methods
- Work Breakdown Structures
- Cost Estimating using WBS
- Summary

Cost and Schedule

- The Skyscraper Video:
  - The owner was concerned about both final cost and time of delivery of building
  - The owner hired a CM, who worked on the owners behalf to manage the project
  - If the project goes over budget, the owner pays for the whole cost overrun
  - If the schedule is not met, the owner looses rent and pays a penalty to tenants!

Labor, Material and Equipment

- The objective of construction management is to efficiently use labor, material and equipment to construct a facility
- A labor force uses equipment to install material in a construction project.
- What amounts of labor and equipment are used in a project greatly affect construction cost and schedule.

Labor

- The cost of labor is often talked about in terms of labor productivity
- Labor productivity is expressed in terms of unit of product per hour.
- Example: yd^3 of placed concrete /hr
- Product may be low-level (yd^3/hr) or high-level (floors/week)

Materials

- Materials delivery to and from a construction site can be:
  - bulk materials (e.g., concrete & earthwork)
  - standard off-the-shelf materials (e.g., valves)
  - fabricated members or units
    - steel members
    - wall panels
    - entire prefabricated units

Construction Equipment

- Affects time and effort needed to do tasks
- Major types of construction equipment:
  - excavation and loading
    - e.g., power shovel, back hoe, loader, clamshell
  - compaction and grading
    - e.g., sheepsfoot roller, bulldozer
  - lifting and erecting
    - e.g., tower cranes, heavy lift cranes
  - mixing and paving

Standard Production Rates (SPR)

- Construction equipment is used to perform repetitive operations:
  - shovels excavate bucketfuls of earth
  - trucks haul earth off the construction site
- The capacity of a piece of equipment is the amount of material handled in one cycle (e.g. bucket = 1.0 yd^3)
- A cycle is the time needed to process that material (e.g., 60 secs/bucket)

Daily SPR

- For a shovel, the daily SPR is:

  (capacity/cycle time)*(operating hrs/day)

  P_e = (1.0 yd^3/ 0.0167 hr)*(8 hr) = 480 yd^3/ day

- For a hauler, the daily SPR is:

  [hauler capacity * operating hours/day] / [loading time + round trip travel time + dumping time]

Daily SPR of Dump Truck

A dump truck with a capacity of 6 yd^3 is used to dispose excavated materials at a dumpsite 4 miles away. The average speed of the truck is 30 mph and the dumping time is 30 secs. If a fleet of trucks is to be used to dispose of 480 yd^3 of *in situ* soil and assuming a swell factor of 1.1, how many trucks are needed for an 8 hr shift? Assume the loader has a capacity of 1 yd^3 and a cycle of 30 secs.

Swell factor indicates how much the soil expands after it has been excavated.

Daily SPR of Dump Truck

Travel time = (2)(4mi)(3600 sec/hr)/(30 mph) = 960 sec
Loading time = (30 sec/1 yd^3) * (6 yd^3) = 180 sec
Total Cycle Time = 180 sec + 960 sec + 30 sec
= 1,170 secs

Daily SPR = (6 yd^3) (8 hr/day)(3600 sec/hr)/(1,170 sec)
= 147.7 yd^3/day
# of trucks = (1.1) *(480 yd^3/day)/ (147.7 yd^3/day-truck)
= 3.57 trucks
Use 4 trucks

Approaches to Cost Estimation

- Cost/sq ft (NY Skyscraper: $350/sq. ft.)
- Unit Cost Method
  - material quantities taken off drawings
  - unit costs (e.g., $/$yd^3$) * quantities ($yd^3$)
- Costs of tasks in project
  - breakdown project into tasks
  - estimate material, labor & equipment costs for each task

Work Breakdown Structure

- To estimate cost of a project task by task, you need a work breakdown structure (WBS)
- Breaks project up into a hierarchy of tasks and subtasks that need to be done to complete the project.

WBS for Construction

- For a construction project, WBS is usually based on components of structure
- For each component, determine the tasks needed to install it
- For each task, you estimate:
  - cost of materials used
  - amount of labor needed and its cost
  - equipment needed (including formwork)

Estimating Durations

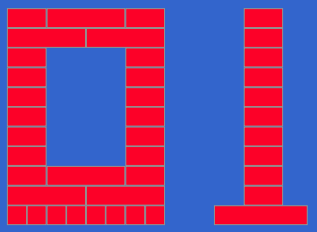
- Depends on crew size used
  - one person
  - standard crew (e.g., brick laying crew)
- Depends on Task Size
- Depends on Work Environment

- Since you all have no experience with your tasks, you need to do *timing studies*

WBS Cost Estimation Form

WBS#	Activity /Tasks	Dur	Rate	Labor Cost	Mat Qty	Unit Cost	Mat Cost	Eqmt Cost	Total Cost
1. comp1									
	1.1 Task	1hr	$15/hr	$15	10	$10	$100	$25	$140
	1.2 Task	2hr	$12/hr	$24	20	$10	$200	$50	$274
	1.3 Task	1hr	$10/hr	$10	30	$10	$300	$25	$335
2. comp2									
	2.1 Task	1hr	$10/hr	$10	10	$10	$100	$25	$135
	2.2 Task	2hr	$15/hr	$30	20	$10	$200	$50	$280
3. comp3									
	3.1 Task	8hr	$12/hr	$96	10	$10	$100	$200	$396
4. comp4									
	4.1 Task	5 hr	$5/hr	$25	40	$10	$400	$125	$550
	4.2 Task	1 hr	$10/hr	$10	10	$10	$100	$25	$135

Lego Wall Example



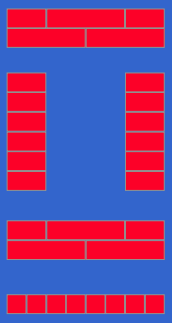
Front Elevation

Side Elevation

Type	Cost
1	150
2	200
3	100

Assume it takes 5 sec to attach a block and labor rate = $10/s

Lego Project WBS



Components:	Tasks:
upper wall (uw)	attach 2 block type 2 attach 2 blocks type 3 attach block type 2
columns A&B	attach 2 blocks type 3 to lw attach 5 blocks type 3 attach 5 blocks type 3
lower wall (lw)	attach 2 blocks type 2 to f attach 2 blocks type 3 attach block type 2
foundation (f)	attach 8 blocks type 1 to base

WBS Cost Estimation Form

WBS#	Activity /Tasks	Dur (s)	Rate	Labor Cost	Mat Qty	Unit Cost	Mat Cost	Eqmt Cost	Total Cost
1. f	1.1 8 B1	40	$10/s	$400	8	$150	$1200		$1600
2. lw	2.1 2 B2	10	$10/s	$100	2	$200	$400		$500
	2.2 2 B3	10	$10/s	$100	2	$100	$200		$300
	2.3 1 B2	5	$10/s	$50	1	$200	$200		$250
3. cols	3.1 2 B3	10	$10/s	$100	2	$100	$200		$300
	3.2 5 B3	25	$10/s	$250	5	$100	$500		$750
	3.3 5 B3	25	$10/s	$250	5	$100	$500		$750
4. cols	4.1 2 B2	10	$10/s	$100	2	$200	$400		$500
	4.2 2 B3	10	$10/s	$100	2	$100	$200		$300
	4.3 1 B2	5	$10/s	$50	1	$200	$200		$250

Cost Estimate, con't

Some tasks do not easily fit under a component in WBS.
E.g., this cost estimate is missing trucking costs:

If a "truck":
- can carry only 10 pieces/trip
- takes 30 secs to make a round trip and costs $15/sec

Then we have the following trucking costs:
- (32 pieces)/(10 pieces/trip) = 4 trips
- trucking costs = (4 trips) * (30 secs/trip) * ($15/sec)
  = $1800

WBS Cost Estimation Form

WBS#	Activity /Tasks	Dur (s)	Rate	Labor Cost	Mat Qty	Unit Cost	Mat Cost	Eqmt Cost	Total Cost
1. f	1.1 8 B1	40	$10/s	$400	8	$150	$1200		$1600
2. lw	2.1 2 B2	10	$10/s	$100	2	$200	$400		$500
	2.2 2 B3	10	$10/s	$100	2	$100	$200		$300
	2.3 1 B2	5	$10/s	$50	1	$200	$200		$250
3. cols	3.1 2 B3	10	$10/s	$100	2	$100	$200		$300
	3.2 5 B3	25	$10/s	$250	5	$100	$500		$750
	3.3 5 B3	25	$10/s	$250	5	$100	$500		$750
4. cols	4.1 2 B2	10	$10/s	$100	2	$200	$400		$500
	4.2 2 B3	10	$10/s	$100	2	$100	$200		$300
	4.3 1 B2	5	$10/s	$50	1	$200	$200		$250
5. deliver									$1800
Total									$7300

Summary

- Cost and schedule are both important to the owner of construction
- Before an owner will commit to a project, an estimate of cost is needed.
- You can estimate cost by:
  - cost/sq.ft approach
  - using quantity takeoffs and unit costs
  - Determining costs of material, labor and equipment for tasks to build components

Outline – Planning and Scheduling

- Introduction
- Planning
- Scheduling
- Gantt Chart
- Critical Path
- Summary

Introduction

- Cost estimation determines what it would cost to build the structure
- Construction plan determines the activities that need to be performed and the order in which they must be performed
- Construction schedule determines when and for how long an activity is performed

Construction Planning

- The objective of construction planning:
  - create hierarchy of tasks to be performed for each work package (called a work breakdown structure)
  - determine durations for each task
  - identify predecessors of each task

Work Breakdown Structure

- WBS can be organized around:
  - components of structure
  - materials being installed
  - location in structure
- Usually, all are used, at different levels
- We used WBS for cost estimation, too

Work Breakdown Structure

Site
Foundation
Building Frame
    Floor 1
        East Side
            Steel Columns
            Floor
                steel deck
                concrete
                    install deck stops
                    place concrete
                    finish concrete
        West Side
    Floor 2

How Many Activities in WBS?

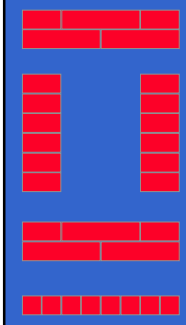
- If activities are too small in size, total may be too unwieldy to be controlled
- if activities are too large, estimates of time and cost may be too coarse
- Define separate tasks for operations:
  - that involve different materials
  - that do not require continuous performance

Activity Durations and Predecessors

- After developing WBS, you need to:
  - determine durations for each task
  - determine what other activities must precede an activity - i.e., predecessors

e.g., before columns can be installed, foundations would have to be completed

Lego Wall WBS



Components:	Tasks:
4. upper wall (uw)	4.1 attach 2 block type 2 4.2 attach 2 blocks type 3 4.3 attach block type 2
3. columns A&B	3.1 attach 2 blocks type 3 to lw 3.2 attach 5 blocks type 3 3.3 attach 5 blocks type 3
2. lower wall (lw)	2.1 attach 2 blocks type 2 to f 2.2 attach 2 blocks type 3 2.3 attach block type 2
1. foundation (f)	1.1 attach 8 blocks type 1

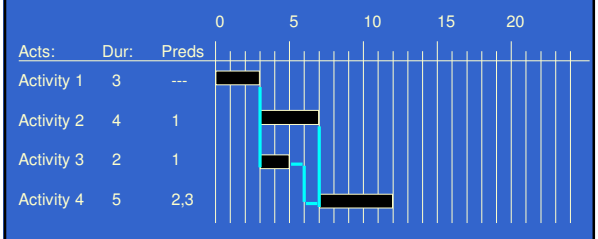
WBS, Durations, Predecessors

WBS#	Activity /Tasks	Dur (s)	Predecessors
1. f	1.1 8 B1	40	
2. lw	2.1 2 B2	10	1.1
	2.2 2 B3	10	2.1
	2.3 1 B2	5	2.1
3. cols	3.1 2 B3	10	2.2, 2.3
	3.2 5 B3	25	3.1
	3.3 5 B3	25	3.1
4. uw	4.1 2 B2	10	3.2, 3.3
	4.2 2 B3	10	4.1
	4.3 1 B2	5	4.1

Scheduling

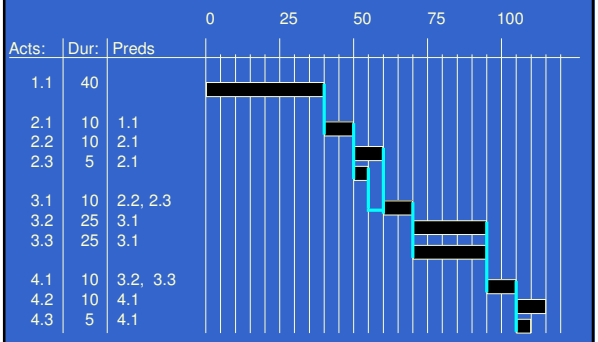
- Once you have defined the WBS, activity durations, and predecessors, you can schedule the activities
- Scheduling is determining when activities are performed in time
- Objective: place activities in time such that they obey predecessor relationships and minimize project duration + ...

Gantt Chart

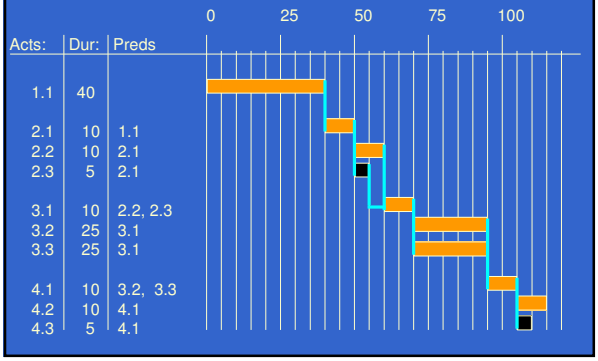


See separate handout for more detail

Gantt Chart for Lego Example



Critical Path



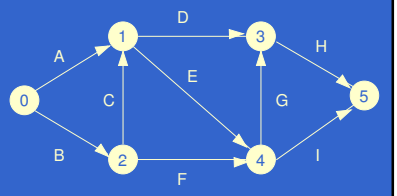
Acts:	Dur:	Preds
1.1	40	
2.1	10	1.1
2.2	10	2.1
2.3	5	2.1
3.1	10	2.2, 2.3
3.2	25	3.1
3.3	25	3.1
4.1	10	3.2, 3.3
4.2	10	4.1
4.3	5	4.1

The Critical Path Method

- You do not really have to build and "eyeball" Gantt charts to find critical path
- An algorithm exists to find:
  - earliest start times & finish times for activities
  - latest start times & finish times for activities
  - the float (allowable delay) associated with each activity
  - the total project delay and those activities on the critical path

The Critical Path Method

Act	Dur	Preds
A	3	--
B	1	--
C	4	B
D	5	A,C
E	3	A,C
F	6	B
G	4	E,F
H	3	D,G
I	5	E,F



Activity-on-Branch Network

Earliest Start Times (EST_i)

CPM Forward Pass:

A & B can start at time 0:
$EST_A = EST_B = 0$

C & F can start when B is done:
$EST_C = EST_F = EST_B + 1 = 1$

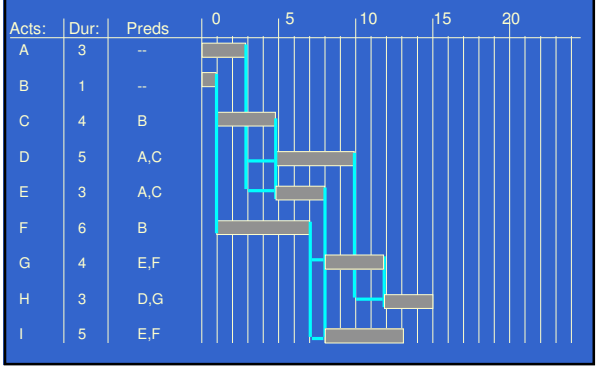
D & E can start when A & C done:
$EST_D = EST_E = MAX[EST_A + 3, EST_C + 4] = MAX[3, 5] = 5$

G and I can start when E & F are done:
$EST_G = EST_I = MAX[EST_E + 3, EST_F + 6] = MAX[8, 7] = 8$

H can start when D&G are done:
$EST_H = MAX[EST_D + 5, EST_G + 4] = MAX[10, 12] = 12$

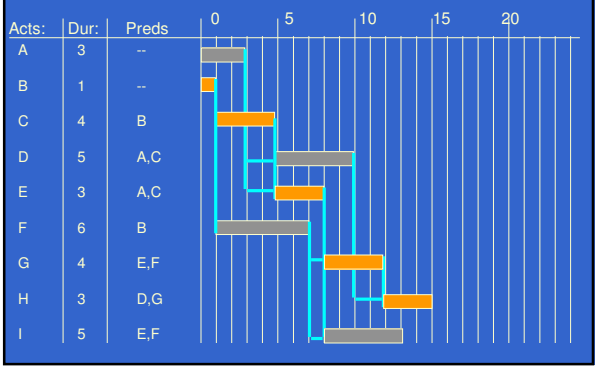
Earliest project completion is when H and I are done:
$EST_5 = MAX[EST_H + 3, EST_I + 5] = MAX[15, 13] = 15$

Build Schedule using ESTs



Acts:	Dur:	Preds
A	3	--
B	1	--
C	4	B
D	5	A,C
E	3	A,C
F	6	B
G	4	E,F
H	3	D,G
I	5	E,F

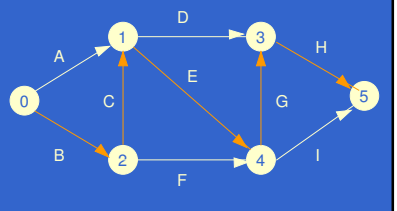
Critical Path



Acts:	Dur:	Preds
A	3	--
B	1	--
C	4	B
D	5	A,C
E	3	A,C
F	6	B
G	4	E,F
H	3	D,G
I	5	E,F

Critical Path

Act	Dur	Preds
A	3	--
B	1	--
C	4	B
D	5	A,C
E	3	A,C
F	6	B
G	4	E,F
H	3	D,G
I	5	E,F



Summary

- Planning determines activities, durations and predecessors
- Scheduling determines when activities are performed in time
- Critical path activities are those that define the project duration
- CPM Algorithm exists for doing scheduling and CP calculations