Detailed Estimation and Pumpstation Overview

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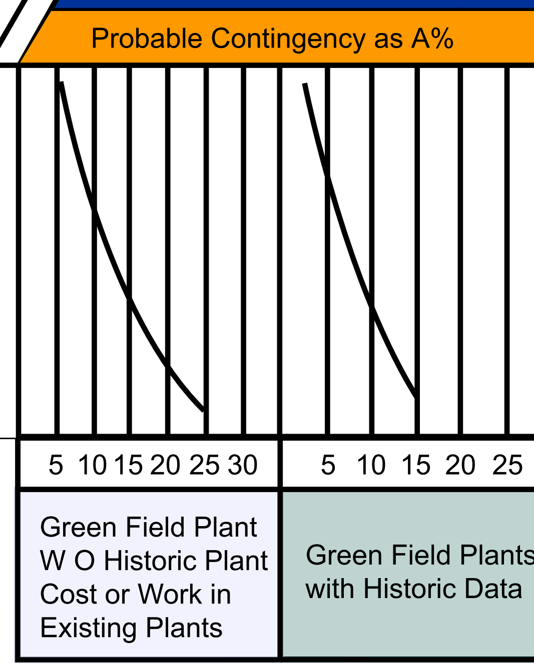
Announcements

- TP2 Due Date: March 15
- PS4 out tonight
  - Due March 19
  - Team project
- Recording of recitation
- Pietroforte Lecture
  - Important lecture – will link to PS 4
- Seminars March 16th & 22nd

Recall the Estimation Phases

Elements Required

Description	Type	Product, Capacity, & Location	Facility Description	Plant Layout	Time to Prepare Estimate	List of Major Equip Priced	General Arrgmts Approved by Client	Outline Scope (General Plant Features)	Electrical Motor List with HP	Pipe & Instrument Diagrams	One Line Electrical Drawings	Drawings of Pipe System Runs	Preliminary Design Drawings	Detail Equipment List - Priced	Detail Scope of Work	Detail Construction Drawings	Detail Specifications	Subcontract & Vendor Firm L.S Quotes
Bid	6	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Engineers	5	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Definitive	4	•	•	•	•	•	•	•	•	•	•	•	•	•	•			
Preliminary	3	•	•	•	•	•	•	•	•	•	•							
Conceptual	2	•	•	•	•	•	•											
Magnitude	1	•	•	•	•													



Basic Data

1. Craft Wage Rates and Fringe Benefits
2. Payroll taxes and Insurance
3. Local Sales Use Other Taxes
4. Design and Construction Schedule
5. Insurance Requirements

Estimate T ypes. (From Building Construction Handbook, 2nd ed., 1975, McGraw-Hill Book Company.)

Detailed Estimates - Methodology

- After most or all of the detail design work is complete, approximate estimates are supplemented by detailed estimates

Stage 1: Quantity takeoff

- Measurement of material & Labor quantities
- Quantities usually recapped by trade for control reasons

Stage 2: Direct Cost contribution

- Σ[Quantity] x [Unit Costs] = Estimated **direct cost** of construction

Notes on Detailed Estimates

- Have differing ranges of uncertainties
  - Distributions typically asymmetric
- More an art than a science – or bookkeeping
  - Detailed quantitative estimates possible – but ignore important qualitative factors
- Wealth of trade-specific and method-specific detail complexity
- Frequently depends heavily on subcontractor estimates (opaque quotes)

Important General Lesson

- Precision in detailed estimated does not mean accuracy!
- Two types of complexity at issue
  - Detail complexity (myriad components required)
  - System complexity (dynamic interactions, etc.)
- Always consider:
  - What are assumptions behind the estimate?
  - What factors are being ignored?
  - How might these factors change the estimate?

Cost Classification

- Direct Cost
  - Labor Cost
  - Material Cost
  - Equipment Cost
  - ST&S Expenses
- Indirect Cost ("Overhead")
  - Interest on loans
  - Trailer rental
  - Office costs
  - AC/heat
  - Planning&logistics
  - Supervision

Overhead Costs

- Project Overhead
  - Project *specific* Management staff, Utilities, Supplies, Engineering, Tests, Drawings, Rents, Permits, Insurance
  - Can and should be estimated directly
  - Can be quite uncertain (mgmt sub. quality, time, etc.)
- Firm Overhead
  - General office Salaries, office rent, utilities, insurance, taxes, shops/storage yards, other expenses
  - Hard to estimate; often use % multiplier
- Sometimes distinction unclear (e.g. lumpy central-office investments)

Project Organization

- ✓ Estimation
  - ✓ Introduction
  - ✓ Conceptual Estimation
    - ✓ Cost indices
    - ✓ Cost-capacity factors
    - ✓ Component ratios
    - ✓ Parameter costs
  - Detailed Estimation
    - Quantity Takeoff
    - Labor Cost Estimation
    - Probabilistic methods

Fair-Cost Estimates

- Prepared from the actual bid documents provided to the bidders (before award)
- Used by owner's representative to evaluate changes (after award)
- May use RS Means or other sources
- No lump-sum subcontract quotations
- Somewhat diff. disaggregation than bid
  - May be simplified number of line items
  - May be more detailed in certain breakdowns (related to subcontractor work)
- *Primary basis for measuring job progress, for scheduling and for cost control.*

Contractor's Bid Estimate

- Low enough to obtain the work, yet high enough to make profit
- Often relies on
  - Historical productivity data for company
  - Intuition on speed of movement
  - Quantity takeoff for most important items
- Sometimes less detailed than fair-cost estimates - subcontractors from 30% to 80% of the project
- Is estimating a streamlined process?

  A look at bids received for a typical project in a competitive area will sometimes show more than 50% difference between the low and the high bidders

Definitive Estimates

- There comes a time when a definitive estimate can be prepared that will forecast the final project cost with little margin for error…
- This error can be minimized through the proper addition of an evaluated contingency
- Four categories for purposes of reviewing definitive estimates:
  - Traditional
  - Design-Build
  - Professional CM
  - Unit-price

Definitive Estimates - Traditional

- Lump-sum - definitive estimate = low bidder's quotation + evaluated contingency
- Fast track guaranteed maximum price, cost-plus-a-fee
  - Definitive estimate will need
    - Detailed project and specifications
    - Firm material quotations
    - Subcontractor quotes
    - Prices for major equipment

Definitive Estimates – Design-Build

- Lump-sum, guaranteed maximum price, cost-plus-a-fee
- Lump-sum can be misleading to an unknowledgeable owner. *The cost is known but the facility that is going to be delivered is unknown*
- In guaranteed maximum price and cost-plus-a-fee contracts the definite estimates can be obtained earlier if compared to the traditional approach because one entity is performing both design and construction

Definitive Estimates - CM

- The definitive estimate can be accurately prepared about the same time as the guaranteed-maximum or cost-plus-a-fee option under traditional approach
  - Examples show that is possible to develop definitive estimates after the detailed design is about 95% complete.

Definitive Estimates – Unit Price

- Unit-Price Projects:
  - Usually heavy construction projects like dams, tunnels, highways, and airports - Prices constants while quantities vary within limits inherent in the nature of work.
  - Quantities may overrun or underrun owing to a number of potential causes such as additional foundation, excavation to solid rock, poor ground conditions, etc.
  - Without reliable geological information the final cost may not be known accurately until the end of the project

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Quantity Takeoff

- Really requires *thinking*!
- Systematic identification of quantities of materials and work required
  - Key features sought
    - Exhaustive
    - Mutually exclusive
- Used to calculate several factors
  - Amount of material (e.g. concrete CY)
  - Equipment utilization
  - Labor
- Breakdown often uses CSI or WBS taxonomies

Quantity Takeoff Subtleties I

- Elements required by construction method
  - E.g. construction joints
- Reuse of materials and equipment influenced by
  - Specification
  - Schedule (itself being estimated, adjusted)
  - Space (can complicate or prevent concurrency – e.g. adequate space for 2 cranes? 2 people?)
- Must estimate both Cost & Time
  - Sometimes requires iteration
  - Hidden dependencies of cost on schedule

Quantity Takeoff Subtleties II

- Division between different parties
  - Easy to think other party taking care of particular elements
    - E.g. think excavation cost is included in unit cost of piping
- Choice of construction approach has big impact
- Estimation of labor costs particularly tricky
  - Prices: In United States, highly detail intensive
  - Productivity: Many qualitative components
- Impact of Type I vs Type II error

Project Organization

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Labor Estimation

- Most subtle, tricky
- For easy transferability , should separate into
  - Q: Unit (Quantity)
  - P: $/hour (Labor Price per hour)
  - W: hour/unit (Labor hours per unit -- productivity)
- Total cost $ = Q * P * W

Labor Price Estimation (P)

- Components
  - Wages (varies by area, jurisdiction, seniority, …)
  - Insurance (varies w/contractor record, work type)
  - Social security (FICA; ½ by employer, employee)
  - Unemployment tax (state)
  - Fringe benefits (apprenticeship, vacation, health…)
  - Wage premiums

Wage Premiums

- For shift work
  - Sometimes adjust hours
- Overtime
  - 1.5-3x for overtime
  - Some crafts paid overtime if over 32 hours
- Hazardous/arduous work
  - Work on swinging scaffold
  - Larger crane
  - Underground work

Further Issues

- Complicated, heterogeneous rules, exceptions throughout US complicate estimation
  - Probably more complicated than for other industries
  - Problem particularly acute for union shops
- Frequently combine into crew-based estimate
  - Reason about price of standard crew
  - Helps factor in labor rules
- Quite substantial variation between contractors in how handle

Labor Productivity Estimation (W)

- Difficult but critical
  - High importance of qualitative factors (environment, morale, fatigue, learning, etc)
  - The primary means by which to control labor costs
- Historical data available
  - Department of Labor, professional orgs, state govs..)

Productivity Considerations

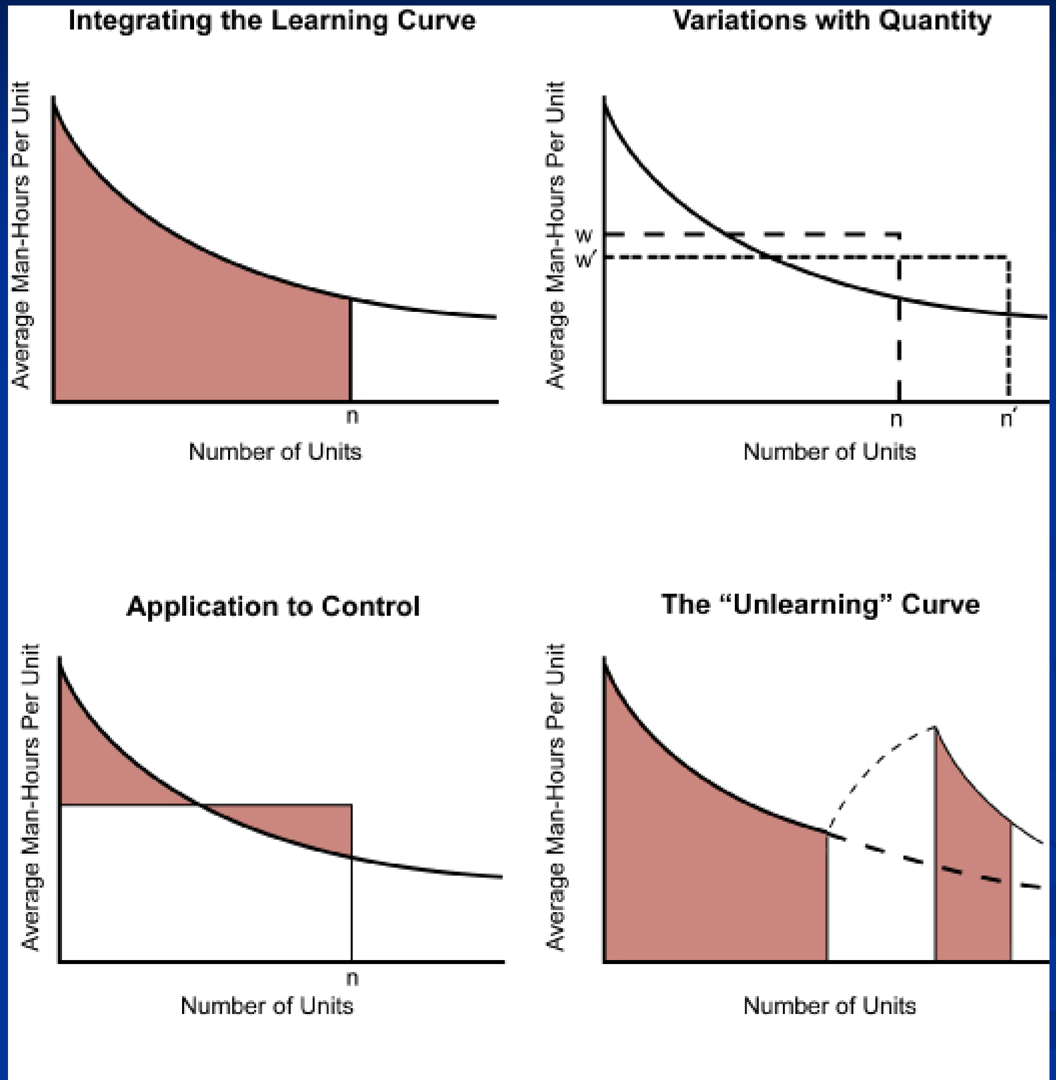
- Considerations
  - Location of jobsite (local skill base, jurisdiction rules)
  - Learning curves
  - Work schedule (overtime, shift work)
  - Weather
    - Elaborate work-arounds, costs
  - Environment
    - Location on jobsite, noise, proximity to matereials
  - Management style
  - Worksite rules

Common Productivity Variations

Productivity Job Factors for Comparable Installations

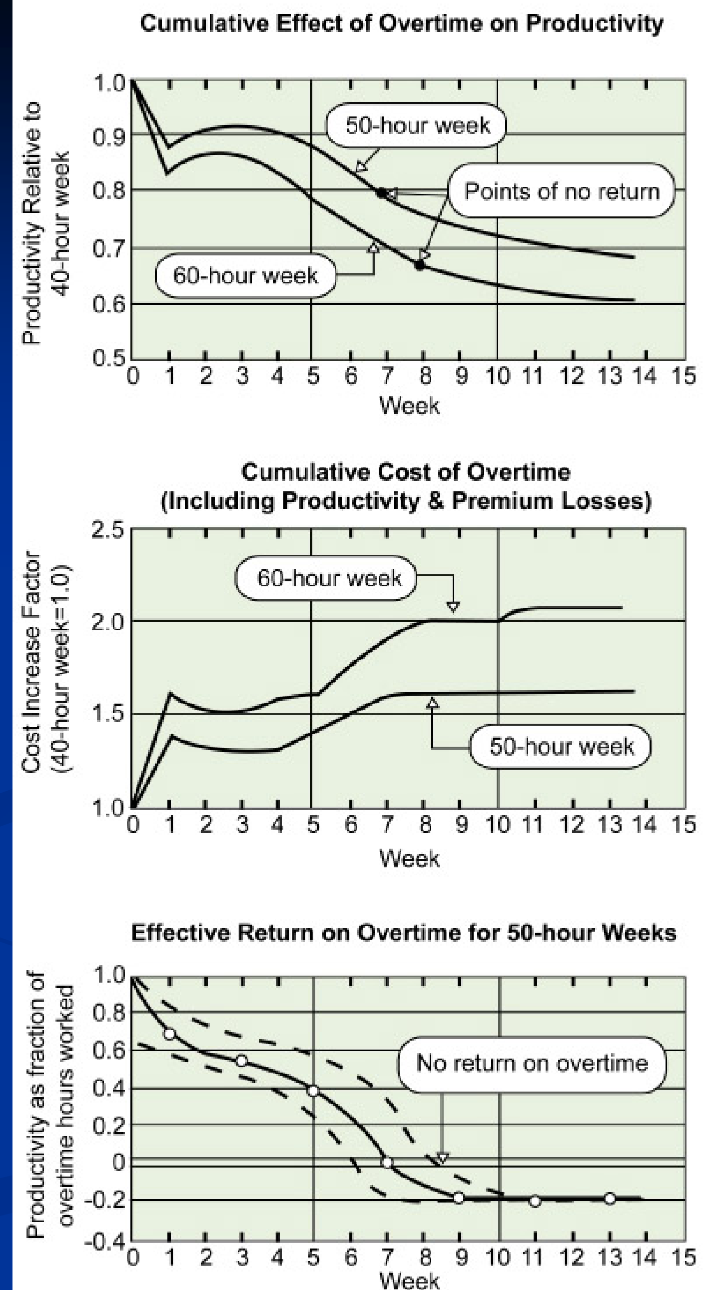
Building Construction	
Nonworking supervision	1.0 to 1.15
Craft skill	1.0 to 1.20
Job conditions	1.0 to 1.20
Work conditions	1.0 to 1.20
Shift work	1.0 to 1.20
Total building range	1.0 to 2.00
Industrial Construction	
Light industrial	1.25 to 2.25
Heavy industrial	1.50 to 3.00
Total industrial range	1.25 to 3.00
Nuclear Power Plants	
Pre-Three Mile Island	2.25 to 4.00
Post-Three Mile Island	3.00 to 5.00
Total nuclear power plant range	2.25 to 5.00

Learning Curves



Learning curve relationships in estimating and control. (From Boyd C. Paulson, Jr., "Estimation and Control of Construction Labor Costs," Journal of the Construction Division, ASCE, vol. 101, no. CO3, September 1975, p. 627.)

Productivity Effects of Overtime



Scheduled overtime versus productivity. (From "Effect of scheduled Overtime on Construction Projects," AACE Bulletin, vol. 15, no. 5, October 1973, pp. 155-160.)

Project Organization

- Award Methods
  - General points
  - Bidding
  - Negotiation
- Lifecycle Costing
- Estimation
  - Introduction
  - Conceptual Estimation
    - Cost indices
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Successive Estimation

- Top-down approach to rapid estimation
- Identify
  - Expected value and variance
  - Irreducible uncertainty due to external factors
- Overall variance is Σ of variance of components
- Break down highest variance items
  - More detail lowers variance
- Result: Frequently only have to estimate small portions of total project to get good estimate

Range Estimation

- Estimate Low-Mean-High of bids will receive
- Estimate range of uncertainty for entire project based on this
  - Can use to reason about confidence intervals

Quantity Take-off

- Assignment 3: Introduction
- Assignment 3: Example
  - Construction Drawings
  - Construction Methods

Assignment 2: What to measure?

- Formwork (Square Feet)
- Formwork Add-on's:
  - Anchor Bolts (qty)
  - Joint Filler (Linear Feet)
  - Chamfer (Linear Feet)
  - PVC waterstop (Linear Feet)
  - Construction Joints (Linear Feet)
- For the *Wet Well Floor*
- For the *Operating Floor*
- For *Internal walls and partitions*

How is it constructed?

1. Install Formwork
2. Install rebar
3. Pour concrete
4. Finish it (small slopes etc.)
5. Wait & Repeat (construction joints)
6. Uninstall formwork
7. Point & Patch, Rub

Think from bottom to top

GRAVITY RULES!

Construction Drawings Navigation

- Drawing Title
- Cross Section
- Detail

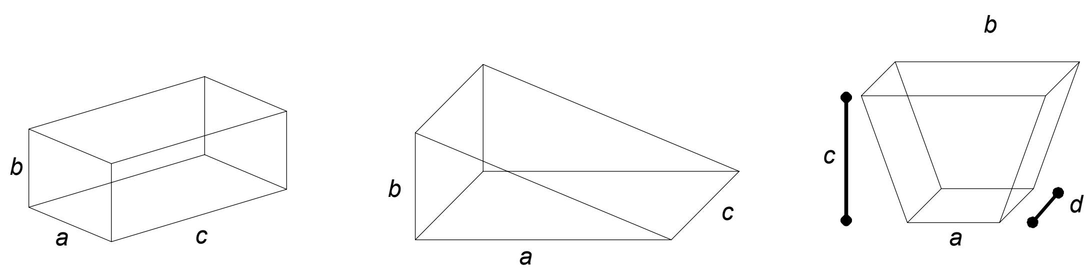
Take-off Template

- Characterize each object you measure (Description)
- Specify which plane you measure
- Specify dimensions of the ENTIRE object
- Try to keep North consistent

Formwork

Total (SF)	Sum

f



Sketch 1 Sketch 2 Sketch 3

Item	Description	Drawings	Sketch	a	b	c	Qty or d	Units	Quantity	Deriver	Signoff
1	Invert Edge Form								Sum		

Example: Define an object

Item	Description
1	**Invert Edge Form**
a	Invert Slab (bottom)
b	Invert Slab (W & E sides)
c	Invert Slab (N & S sides)
d	

Example: Find relevant drawings

Example: Define Planes & Dimensions

Sides of Invert Slab	S-1101, S-1105	1	44.00	6.00	54.50		SF	1,182.0

Casting a concrete slab on grade

Sequence: **(You are not responsible for this formwork in the assignment)**

1. Form and edges
2. Reinforcement and embedment
3. Striking off or straightedge
4. Floating (if smoother surface is needed)
5. Control joints
6. Troweling (if very smooth surface is needed)
7. Curing (under damp conditions)

Casting a concrete wall

Sequence:

1. Coated form (one side only)
2. Reinforcing
3. Ties and inspection
4. Coated form (2nd side)
5. Placing concrete
6. Curing
7. Stripping of formwork and snapping off ties
8. Point and Patch
9. Rub