Award Methods and Project Estimation I

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Talk Announcement I

- **Joachim Eble** (Title TBA)
  - Major figure in green building design
- March 16, 2004, 4 – 6 PM

Talk Announcement II

- "Contour Crafting Construction: Houses Straight from the Printer"
  - Behrokh "Berok" Khoshnevis, Professor (USC)
- Monday, March 22, 2004
  - 2:00 p.m. - 4:00 p.m

Themes from Granli Talk

- Key megaproject issues
  - Management of uncertainty
  - Need for lead indicators to spot problems early
  - Whole lifecycle management
  - Dealing with entire project ecosystem
    - Procurement
    - Partner issues
    - Governance
    - Political support
    - Community concerns

Project Organization

- Award Methods
  - General points
  - Bidding
  - Negotiation
- Lifecycle Costing
- Estimation
  - Introduction
  - Conceptual Estimation
    - Cost indices
    - Cost-capacity factors
    - Component ratios
    - Parameter costs
  - Detailed Estimation
    - Quantity Takeoff
    - Labor Cost Estimation
    - Probabilistic methods

Award Methods: Contractor Selection

- Extremes

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Bidding

- Variants
  - Low bid
  - Multi-parameter bidding
    - Low bid plus arithmetic combination of other factors
    - Low bid divided by ranking of other factors
- To allow for fast-tracking may bid early (30%)
- Fixed price low bid is win-lose
- Typically associated with lump-sum contract
- Prequalifications critical

Bidding Advantages

- Can get good price
- Transparency
- Well-understood method
- Approved by regulatory structures
- For owner: Contract terms can be set by owner

Bidding Disadvantages

- Can set up win-lose situation
- Insufficient consideration of design before pricing
- Low bidders can be unreliable -- Prequalify aggressively!
- Can be very bad for design (design-build, CM at risk)
- Pressure for lowest bid can eliminate profit from bid
  - Cutting corners
  - Placement of low-quality personnel
  - Bad feelings

Bidding Tradeoffs

- Time provided to bidders to review documents
  - Too long: Construction delayed
  - Too short:
    - Bids low-quality because too little time to review contract docs (incorporate high risk premium or unrealistically low)
    - Few bidders willing to participate
- Bid count
  - Too many bidders: Scare away best contractors
  - Too few bidders: Bid not competitive

Bidding Metrics

- Most common: Price alone
- Bidding "cap": Bid on how far can go with set amount of money
- Multi-parameter bidding (increasingly popular)
  - Consider non-price items (time, quality, qualification)
  - A+B Additive measures
    - Price+($/day)*days (common for retail), Price+qualification+design rank, price+design rank,…
  - A/B (e.g. B scoring along some metric: Design, etc.)

Bidding Process

- A/E or CM oversight typical
- Publicity (specifies qualification requirements)
- Provide bid documents
  - E.g. fair cost estimate, sample contract, general & specific conditions, specifications & drawings, supplemental provisions
- Answer RFIs
- Pre-bid conference
  - Explain scope, working conditions, answer questions, documented in writing)

Qualifications

- Common items for qualifications
  - Bonds/Insurance (bid, performance, payment)
  - Safety record
  - Reputation
  - Financial strength
  - Total/Spare capacity
  - Licensing
  - Background in type of work
  - Experience in local area/labor market
  - Management system (QA, planning, estimation, control)
  - Interest, adaptability shown

Public vs. Private Bidding

- Public Bidding
  - Must be publicly advertised (posting in newspapers, public building, etc.)
  - Qualification occurs after submission of bids
  - Typically 60 day period in which can submit bids
- Private Bidding
  - May be by invitation only
  - Qualification occurs before submission of bids

Dealing with Way-Out Low Bids

- Forcing collection from unrealistically low bids is dangerous
  - Construction highly contentious, poor morale
    - Risk of extreme corner cutting
  - Default is possible
    - Disruption
    - Insurance companies fulfilling performance bonds very difficult to work with

Subcontracting Bid Issues

- GCs solicit bids from subcontractors
- GCs push subs for lowest possible price before GC bids
  - GC not obligated to use quoted subcontractor
- Can lead to serious predatory behavior
  - Bid shopping (before *and* after GC wins bid)
  - Bid peddling (unsolicited calls from subs to GCs after GC wins bid)
- Some owners/states require listing of chosen subs at bid time or assign based on sub-bidding

Bonding

- Bid
  - Public
    - ~20% or as low as 5% of Bid
  - Private
    - 5% to 10% of Bid
- Miller Act 1935
- Performance
  - 100% Complete Job at Bid Price
- Payment
  - Cover Unpaid Bills by Contractor
    - 50% for > $1M
    - 40% for $1M < X < $5M
    - 2.5M for > $5M
- Cost
  - 1% per $1K up to $200K
  - Lower for > $200K
- Calculation
  - No Track Record: 5 or 6 Net Quick Assets
  - Old Reliable Record: 40+ Net Quick Assets

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Negotiation

- Typically selected based on reputation, qualifications
- Typically used in pure form for two cases
  - Very simple
    - Use trusted, familiar party
  - Very complex/big
    - Get contractor involved in design, start work early
- Requires relatively savvy owner
  - Evaluate proposals, monitor performance
- Important even for DBB for post-bid changes

Negotiation Considerations

- Can get win-win because of differences in
  - Risk preferences
  - Relative preferences for different attributes
- Goal is to find a pareto optimal agreement
- Key skill in negotiation: Ability to find win-win options

Negotiation Tips

- Try to maintain clear sense of reservation price
  - Price or conditions under which will accept offer
- Want to adopt some objective basis for position
  - Without this impersonal criteria, other party can take disagreements personally as arbitrarily demands
- Discuss multiple issues at once
  - Permits trading off issues flexibly
- Formal exposure good–but experience gives edge

Negotiation Tips 2: Major Sins of Negotiation (Thomson, 2001)

- Leaving money on the table: Failing to identify and use win-win opportunities
- Settling for too little: Unnecessarily large concessions
- Walking away from the table: Rejecting terms that are favorable, often due to pride
- Settling for terms worse than existing alternative: Pressure to reach some deal leads to opportunity less attractive than opportunity cost

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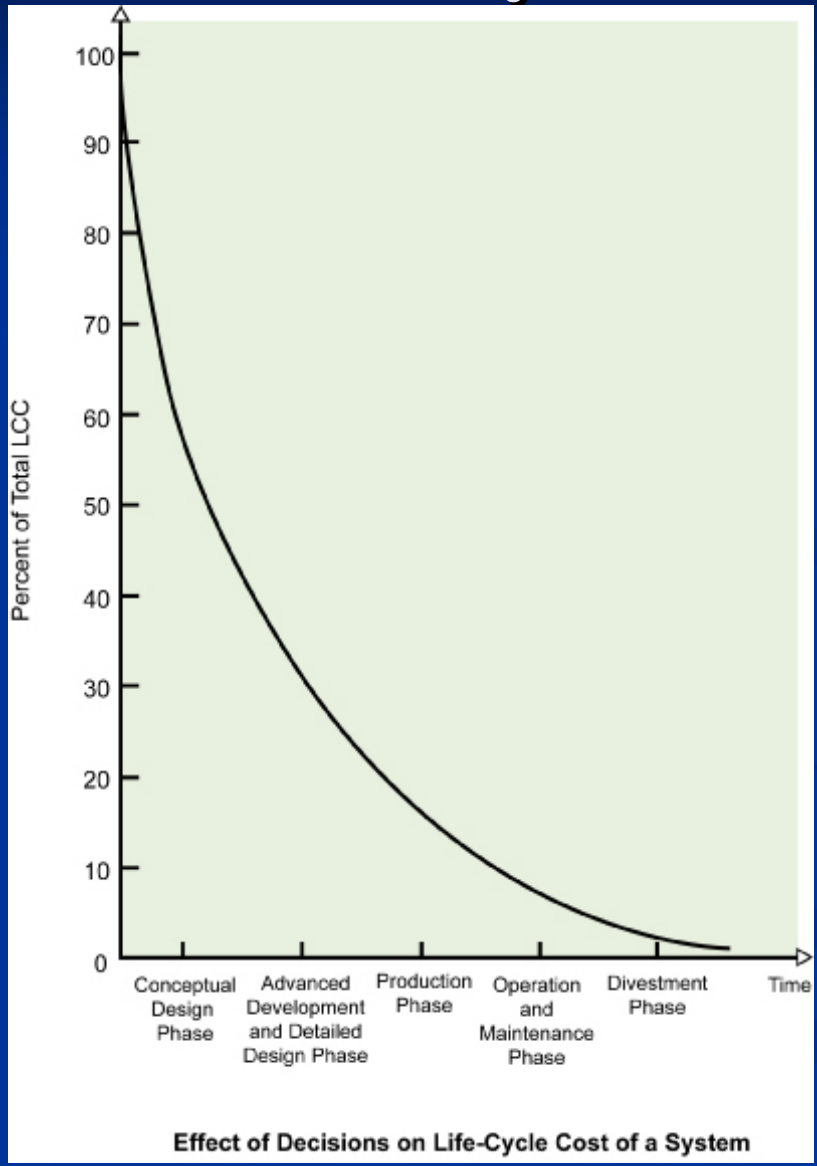
Life-Cycle Costing Stages

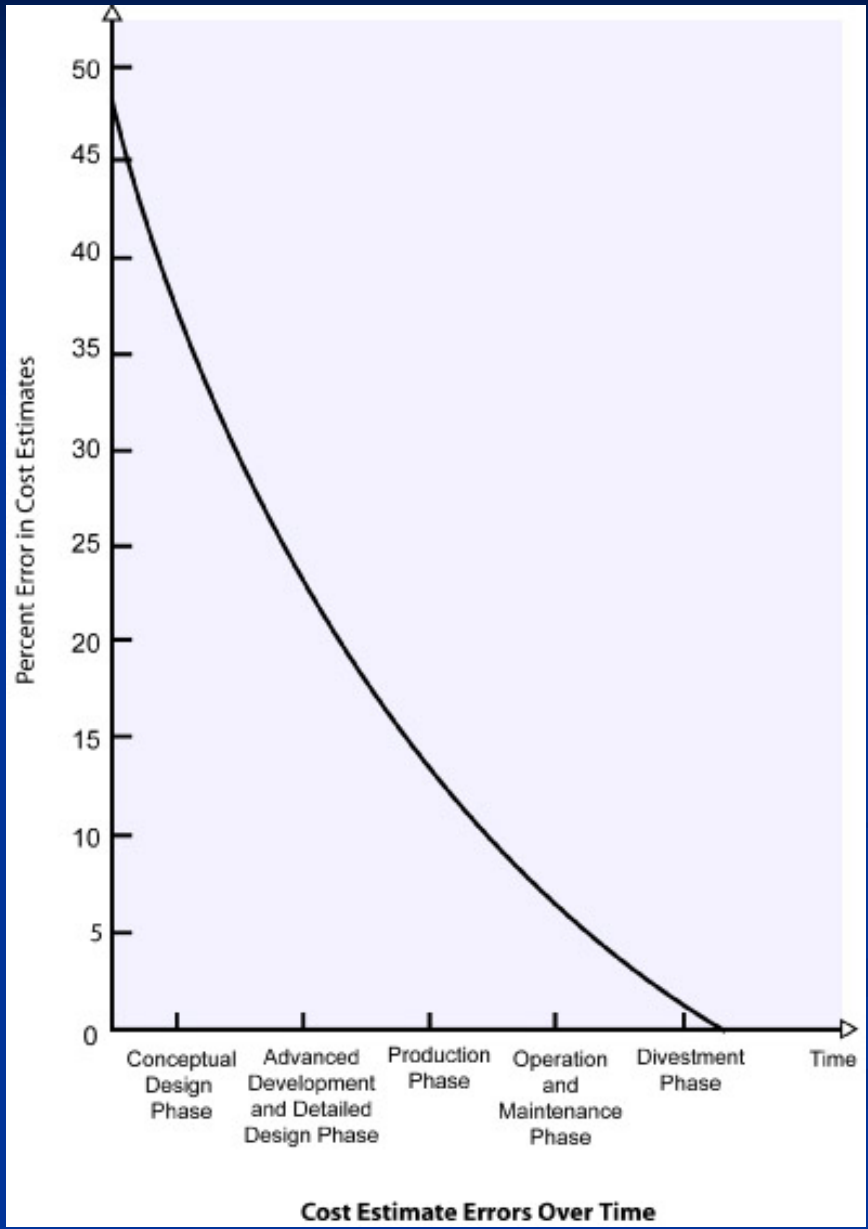
- Conceptual Design Phase
- Detailed Design Phase
- Production Phase
- Operation and Maintenance Phase
- Divestment Phase

Effect of Decisions on Life-Cycle Cost of a System



Effect of Decisions on Life-Cycle Cost of a System

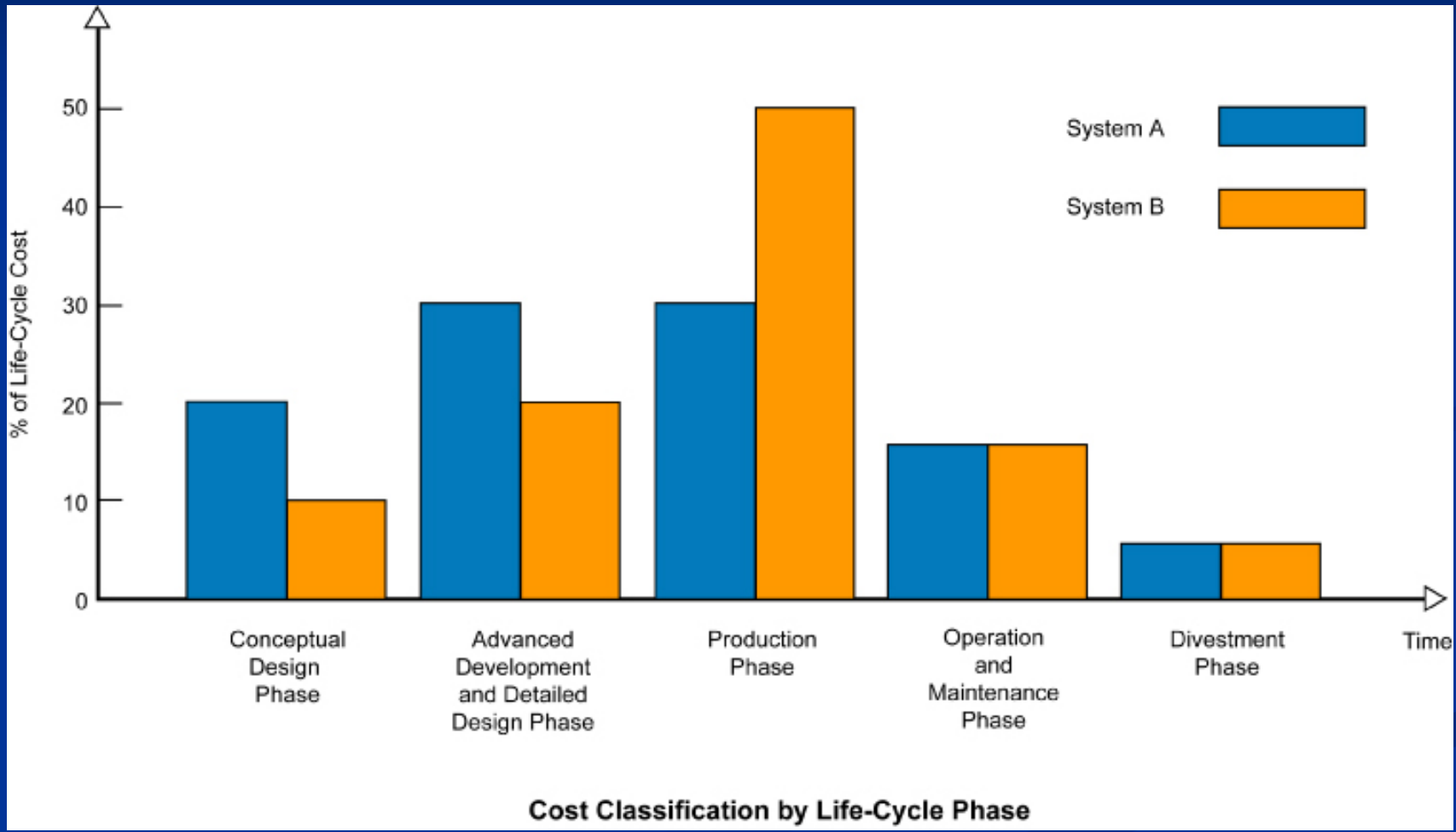
Cost Estimate Errors Over Time



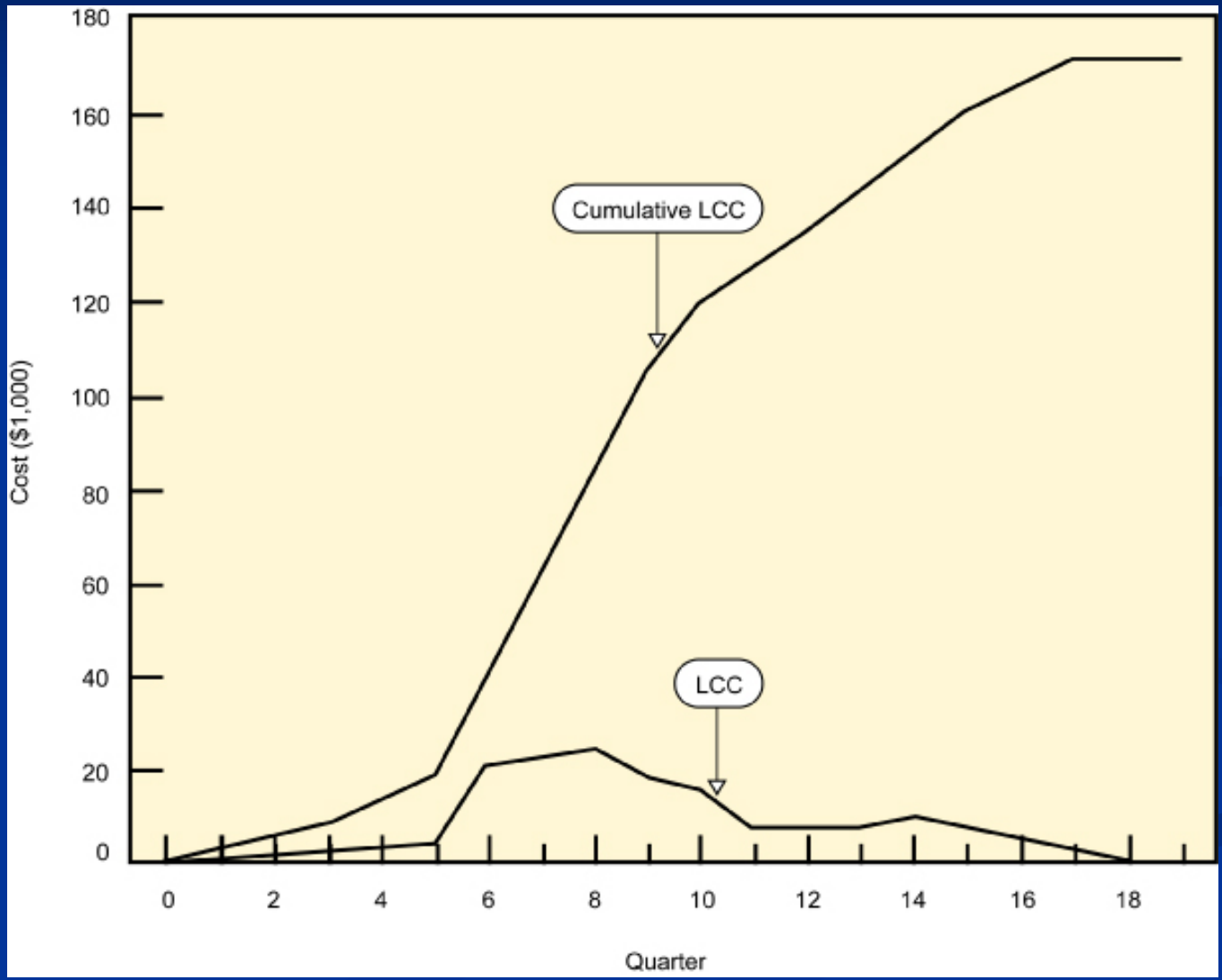
Items where LCC Important

- Focus on non-static portions of structure
  - Portions that move, undergo a lot of use/wear, require maintenance or replacement
- Examples
  - Carpets, HVAC, electrical system, finishings, parking, roofing,…
- Interdependencies critical
  - E.g. HVAC and insulation considered together

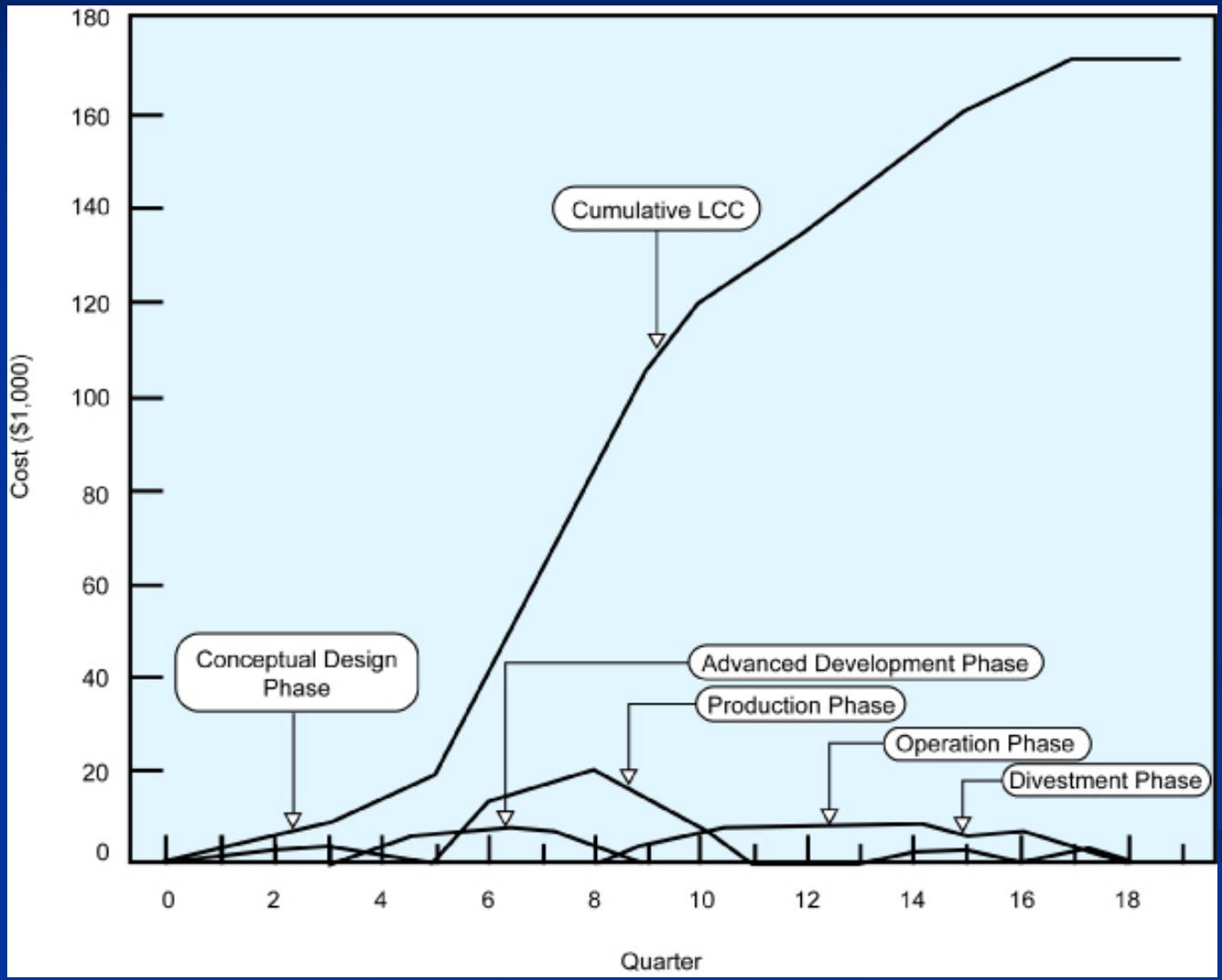
Cost Classification by Life-Cycle Phase



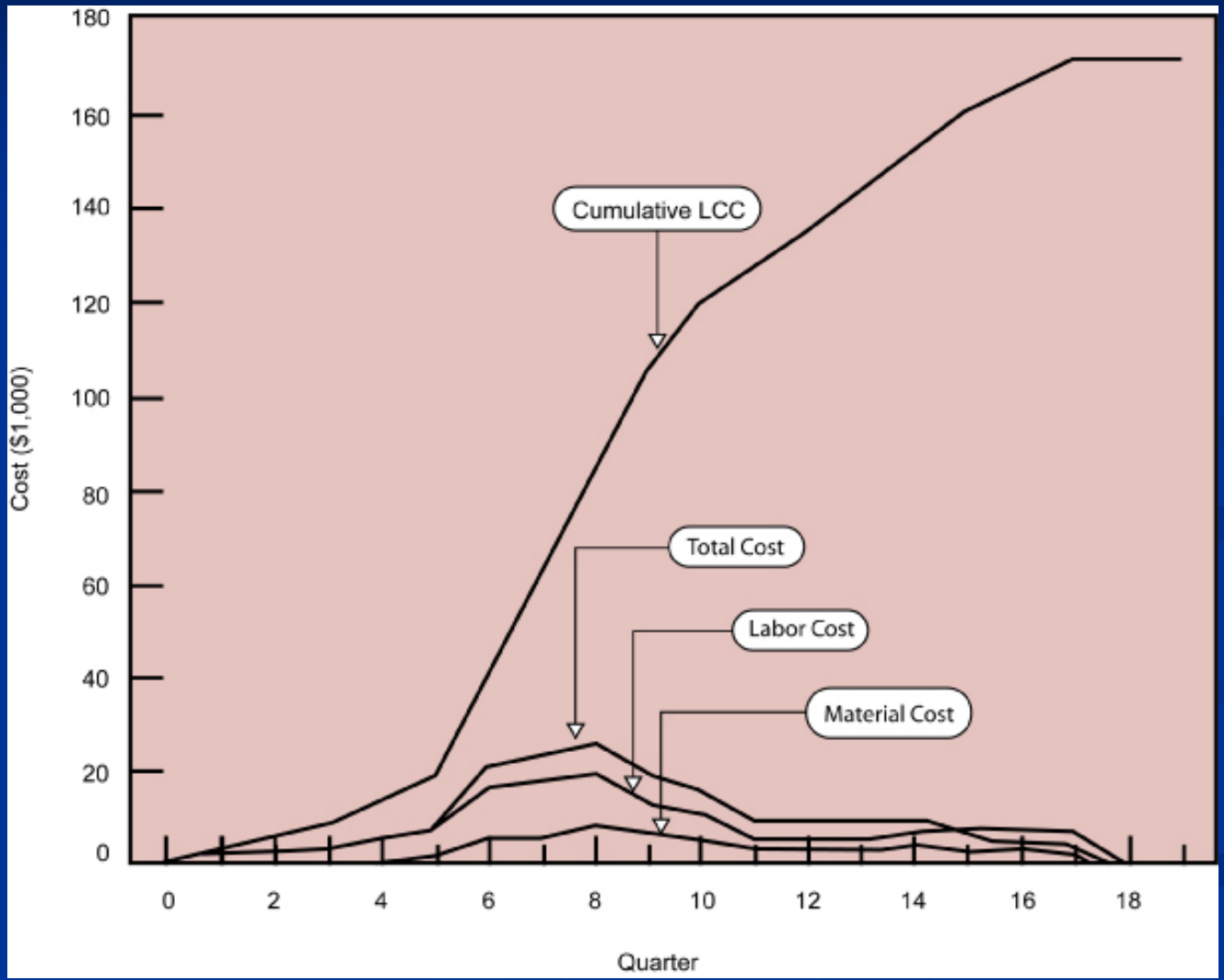
Total Life-Cycle Cost of the System



Life-Cycle Cost by Phase



Cost Breakdown by Labor and Material



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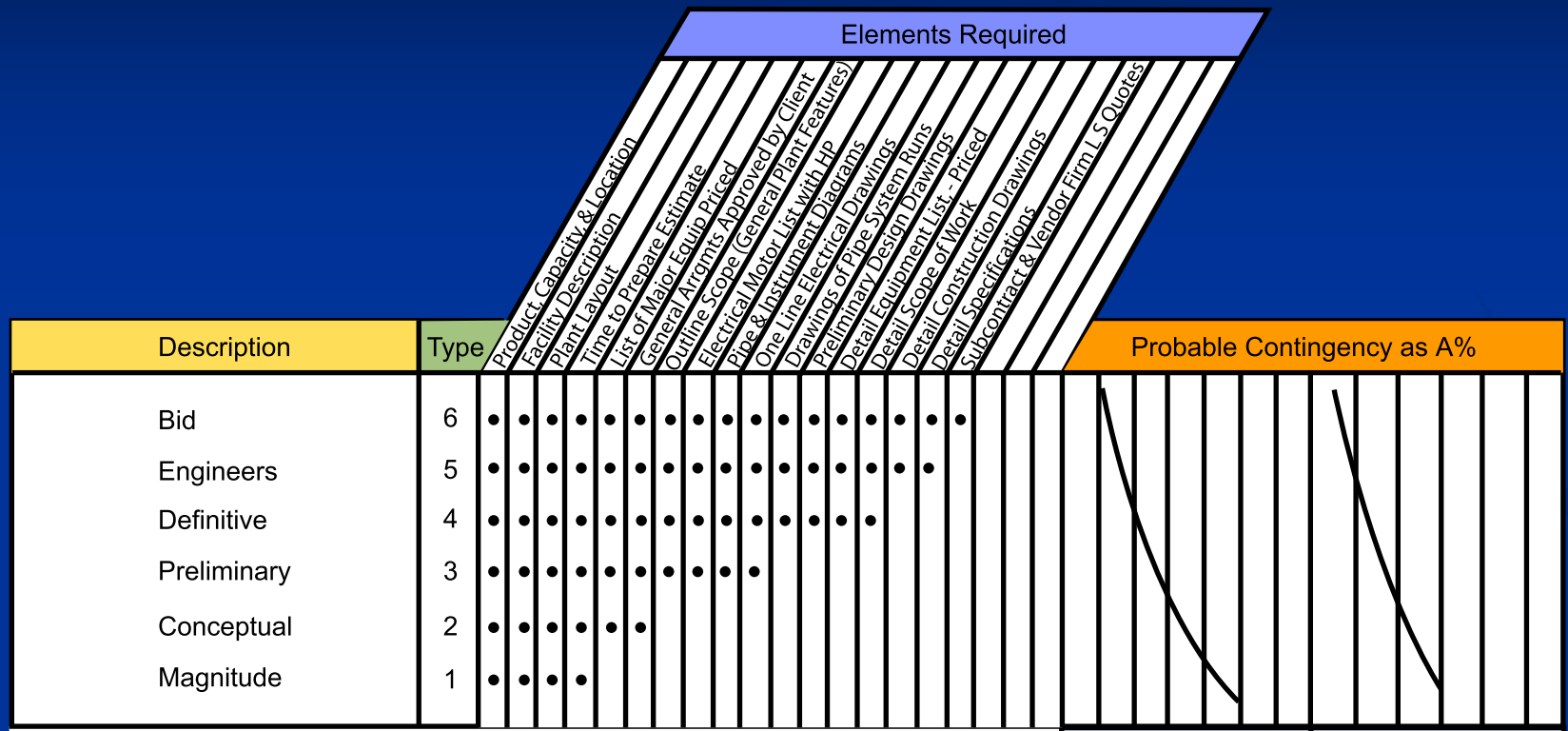
Estimation Levels - Introduction

- Different types of estimates are required as a project evolves
  - Conceptual and Preliminary Estimates
    - Prior to engineering design completion
  - Definitive Estimates
    - forecast the project cost within allowable limits from a combination of conceptual and detailed information often including partial contract and other procurement awards
  - Detailed Estimates (Engineer's and bidding)
    - Prepared from completed plans and specifications

Elements of Estimation



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.)

Further Estimate Details I

				Estimating Methods Used/Cost Basis			
Class	Project Phase	Approx. Design Complete	Typical Contingency	Information Required	Major Equipment	Other Materials	Labor
1: Order of Magnitude	Business Planning	< 1%	100-200%	Project purpose/ product	Index methods		
2: Conceptual	Feasibility	2-5%	30-50%	Facility capacity Site selected (perhaps) Owner's Project Mgt. selected Consulting engr., CM, or turnkey contractor selected	Index methods Cost-capacity curves Comparable projects Industry published data Licenser estimate		
3: Preliminary	Conceptual Design	15-30%	15-40%	Facility capacity Geotechnical info PID's, PFD's Preliminary equipment list Preliminary Project Schedule	Cost curves Vendor quotes by phone Recent purchases Published estg. data	Ratio to major eqpt. Ratio from similar facilities	Labor / material ratios
4: Definitive	Detailed Design	50-75%	10-20%	Detailed design dwgs. Specifications Contracting plan Long-lead equipment ordered CPM-level schedule	Eqpt. vendor quotes Long-lead equipment ordered Escalation defined	Ratio to major eqpt. Escalation defined Key quantities defined	Labor / material ratios Labor-hour units Productivity for area Wage rates
5: Engineer's or Owner's	Pre-bid	90%	5-10%	Complete design & bidding data	Long-lead eqpt. prices firmed Deliveries defined	Detailed take-off Firm unit cost quotes	Defined indirects
6: Bid Level	Construction	100%	5%	Contractors, sub's & vendors. CPM, Resource-leveled schedule Bid Addenda	Actual or committed costs to-date	Bulk mat'l prices and delivery terms quoted	Detailed evaluation of labor crafts and productivity Sub bids rec'd

Further Estimate Details II

Class	Order of Magnitude	Conceptual	Preliminary	Definitive	Engineer's or Owner's Control	Bid Level
Estimate Prepared by	Owner	Owner, Consultant, CM or Turnkey Contractor	Owner, Consultant, CM or Turnkey Contractor	Owner, Consultant, CM or Turnkey Contractor	Owner, Consultant, CM or Turnkey Contractor	Construction Contractor
Contingency and Escalation Estimated by	Single %	Broad evaluation	Broad evaluation	Detailed evaluation	Detailed estimate	Detailed estimate Risk simulation
Engr. & Mgt. Fee	% of constructed cost	% of constructed cost	Broad estimate	Broad estimate	Detailed estimate	Detailed estimate
Contractor's Overhead & Profit	Implicitly included	% of direct cost	% of direct cost	% of direct cost	% of direct cost	Detailed estimate
Const. Plan	None	Not required	Desirable	Desirable	Highly Desirable	Required

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Conceptual/Preliminary Estimates

- Help decide feasibility
- Very useful for rapid iteration of design plans
- Great variability according to type
- Categories:
  - Time-referenced cost indices
  - Cost-capacity factors
  - Component ratios
  - Parameter costs

Cost Indices

- Show changes of costs over time
- Changes in:
  - Technology
  - Methods
  - Productivity
  - Inflation
- Both *input* and *output* cost indices available
- Published periodically by Engineering News-Record and other publications

Input Cost Indices

- Reflect price changes for a certain "basket" of goods
  - Like Consumer price index
- Very general
- Problems
  - May not reflect particular inputs of project
  - Ignore productivity changes
  - Ignore technology changes
  - Competiveness of contractors (lowered overhead)

Cost Indices Component Calculations

- ENR's Building Cost Index is computed as follows:
  - Components:
    - 1,088 board feet of lumber (2x4, 20-city average)
    - 2500 pounds of structural-steel shapes (20-city average, base mill price before 1996, fabricated after 1996
    - 1.128 tons of Portland cement (bulk, 20 city average)
    - 66.38 hours of skilled labor (20-city average of Bricklayers, Carpenters, and Structural Ironworkers)
- http://www.enr.com/cost/costbci.asp

Cost Indices Time Conversion

- We convert from one base period to another
  - "current cost" = 3802 (February 2004)
  - Base cost (1913) = 100
  - Index on 1913 base = 3802%
- Example 1:
  - Warehouse estimate: Assume you have an estimate to a similar warehouse completed in 1978 for a cost of $4,200.000. We are planning to build the new one in 2002. The ENR index for 1978, relative to the base date of 1913, was 1654%
  - 3802%/1654% x 4,200,000 = $9,654,413.54 ~ $ 9,650,000

Output Cost Indices

- Look at historical costs for similar projects
- Tend to be rather narrow in definition
  - May not find close match for facility in question

Cost Indices Use and Accuracy

- 20% to 30% Accuracy
- Negligible time and effort
- Valuable for Preliminary Planning

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Cost-Capacity Factor

- Apply to changes in size, scope, or capacity of projects of similar types
- Reflect the nonlinear increase in cost with size (economies of scale, learning curves)
- $C_2 = C_1 (Q_2/Q_1)^x$
  - Where
    - C_2 = estimated cost of the new facility with capacity Q_2
    - C_1 = known cost of facility of capacity Q_1
    - x = the cost-capacity factor for this type of work

Cost-Capacity Factor II

- X is empirically derived factors based on well-documented historical records for different kinds of projects
- Q are parameters that reasonably reflects the size of the facility (barrels per day produced by a refinery, tons of steel per day produced by a steel mill, gross floor area for a warehouse, etc)

Cost-Capacity Factor Example

- Consider the cost-capacity factor x = 0.8 for a warehouse.
- We have available an estimate for a similar warehouse located nearby with a usable area of 120,000 square feet (from Example 1), cost $4.2E6 in 1978.
- The prospective owner for the new warehouse wants a structure with a usable area of 150,000 square feet

Cost-Capacity Factor Calculations

- Solution:
  - $C_2 = 4{,}200{,}000 \times (3802/1654) \times (150{,}000/120{,}000)^{0.8} = \$11{,}541{,}278$
  - Cost-capacity factor can be accurate to within 15 to 20% of actual costs

Pena-Mora, 2003

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Component Ratios

- Focus on Major Equipment
  - Compressors
  - Pumps
  - Furnaces
  - Refrigeration Units
  - Belt Conveyors
  - Turbine Generators
- "Equipment-Installation-Cost-Ratios"
- "Plant-Cost-Ratios"

Component Ratios: Installation Cost

- Multiply the Purchase Cost by Installation Cost Factor
- +/- 10 to 20% Accuracy

Component Ratios Factors

Typical Equipment Installation Factors*

ITEM	INSTALLATION COST, %
Belt conveyors	20 - 25
Bucket elevators	25 - 40
Centrifugals, disk or bowl	5 -6
Top suspended	30 - 40
Continuous	10 - 25
Crystallizers	30 - 50
Dryers, continuous drum	100†
Vacuum rotary	150 - 200†
Rotary	50 - 100†
Dust collectors, wet	220 - 450†
Dry	10 - 200†
Electrostatic precipitators	33 - 100†
Electric motors plus controls	60
Filters	25 - 45
Gas producers	45 - 250
Instruments	6 - 300
Ion exchangers	30 - 275†
Towers	25 - 50
Turbine generators	10 - 30

* Adapted from F. C. Jelen (ed.), *Cost and Optimization Engineering*, McGraw-Hill Book Company, New York, 1970, p. 316.

† Includes accessories.

Component Ratios Plant Cost

- Plant-cost-ratios use equipment-vendor-price-quotations

ITEM	COST		FACTOR	PLANT COST
Blowers and Fans	$ 10,000	×	2.5	$ 25,000
Compressors	50,000	×	2.3	115,000
Furnaces	100,000	×	2.0	200,000
Heat Exchangers	80,000	×	4.8	384,000
Instruments	50,000	×	4.1	205,000
Motors, Electric	60,000	×	8.5	510,000
Pumps	20,000	×	7.0	140,000
Tanks	125,000	×	2.4	260,000
Towers	200,000	×	4.0	800,000
Total	$ 685,000			$ 2,639,000

Component Ratios Factors

Process-plant Cost Ratio from Individual Equipment*

EQUIPMENT	FACTOR†
Blender	2.0
Blowers and fans (including motor)	2.5
Centrifuges (process)	2.0
Compressors:	
Centrifugals, motor-driven (less motor)	2.0
Steam turbine (including turbine)	2.0
Reciprocating, steam and gas	2.3
Motor-driven (less motor)	2.3
Ejectors (vacuum units)	2.5
Furnaces (package units)	2.0
Heat exchangers	4.8
Instruments	4.1
Motors, electric	8.5
Pumps:	
Centrifugal, motor-driven (less motor)	7.0
Steam turbine (including turbine)	6.5
Positive displacement (less motor)	5.0
Reactors-factor as approximate equivalent type of equipment	
Refrigeration (package unit)	2.5
Tanks:	
Process	4.1
Storage	3.5
Fabricated and field-erected (50,000 + gal)	2.0
Towers (columns)	4.0

* From W. F. Wroth, "Factors in Cost Estimation," *Chem. Eng.*, vol. 67, October, 1960, p. 204; and F. C. Jelen (ed.), *Cost and Optimization Engineering*, McGraw-Hill Book company, New York, 1970, p. 316.

† Multiply purchase cost by factor to obtain installed cost including cost of site development, buildings, electrical installations, carpentry, painting, contractor's fee and rentals, foundations, structures, piping, installation, engineering, overhead, and supervision.

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Parameter Costs Source Data

- Commonly used in building construction
- ENR "Quarterly Cost Roundup"
- R.S.Means "Means Square Foot Costs"
  - NB: Different from *RS Means Building Construction Cost Data!*

Parameter Costs Characteristics

- Relates all costs of a project to jut a few physical measures, or "parameters", that reflect the size or scope of the project
- Warehouse - the "parameter" would be "gross enclosed floor area"
- With good historical records on comparable structures, parameter costing can give reasonable levels of accuracy for preliminary estimates

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