

Chapter 14

Managing Projects and Programs

*“A journey of a thousand miles begins
with a single step”*

Chinese proverb

Carl D. Martland, “Toward More
Sustainable Infrastructure”

“Successful organizations create projects that produce desired results in established time frames with assigned resources.”

S.E. Portny et al, **Project Management**, 2008, p. 2

Management of Projects and Programs

- Project management:
 - Detailed planning, scheduling, monitoring and adjusting the processes involved in implementing a specific project
- Program management
 - Evaluating and then managing a series of related projects using common processes and evaluation criteria

Stages of Project Management

1. Preparing to implement the project
2. Managing construction
3. Managing the transition from construction to operation
4. Completing the project
5. Assessing or auditing the project

Preparing to Implement the Project: Sub-Tasks

- Financing
- Acquisition of land
- Public approvals
- Construction strategy
- Marketing
- Transition planning

Preparing to Implement the Project: Potential Pitfalls

- As a result of general economic conditions, difficulty in obtaining financing may cause delay or cancellation
- Inability to acquire the necessary land may require restructuring of the project
- A major client may back out of a lease, so that it becomes impossible to get a construction loan

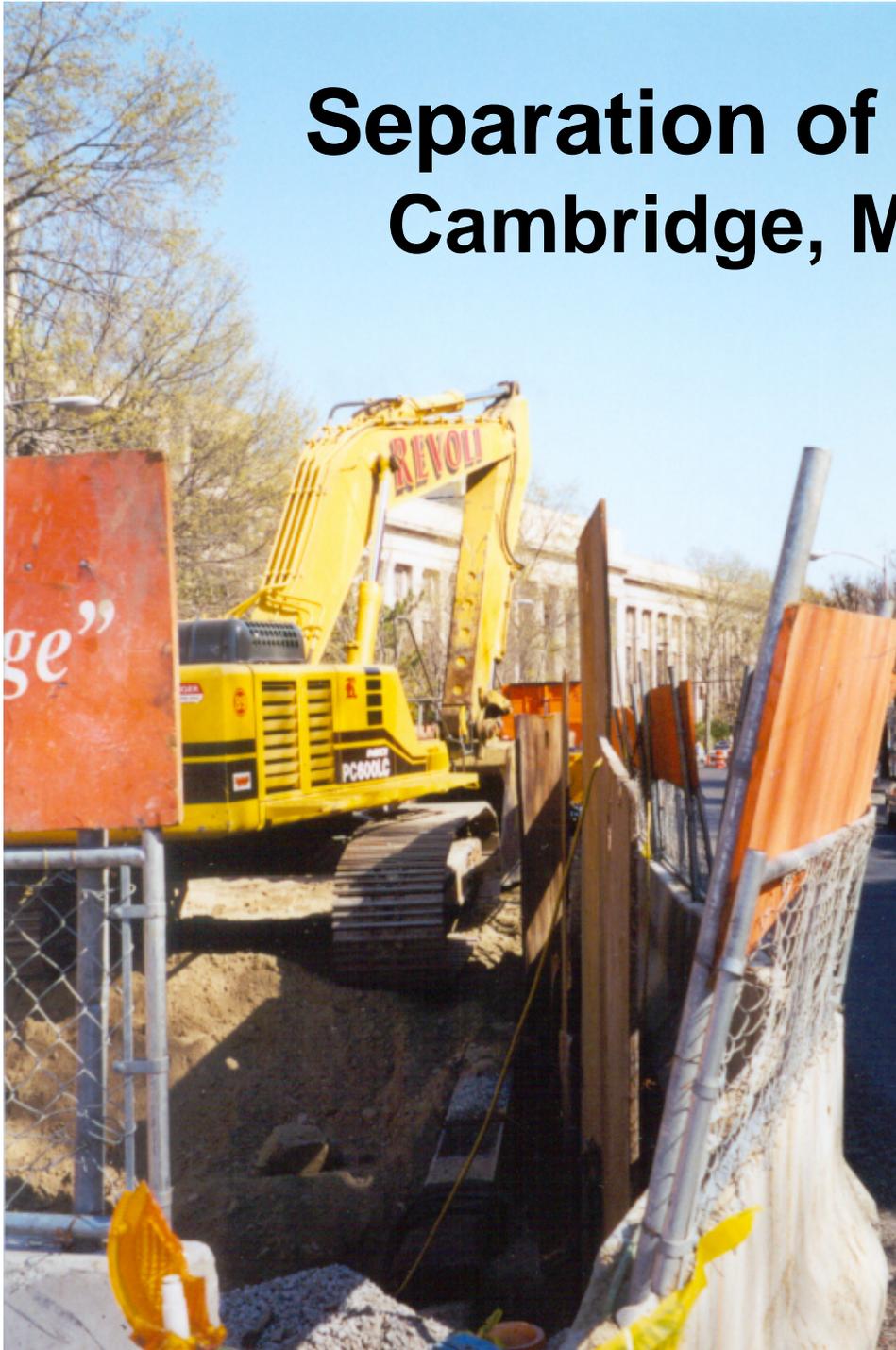
Managing Construction: Sub-Tasks

- Preparing a network diagram
- Scheduling
- Budgeting
- Risk management planning
- Mitigating social and environmental impacts

Managing Construction: Potential Pitfalls

- Budgets and schedules may reflect hopes or past experience, not reality
 - Delays and overruns are very common
- Work may be more dangerous than expected
 - Panama Canal
- Construction process may be unworkable
 - North Atlantic Cable
- Project might not be sustainable socially.
 - Opposition to highways in Boston & San Francisco

Separation of Storm Sewers Cambridge, Massachusetts



- Prevent run-off from storms causing overflow of sewerage into river.
- Managers coordinated project with upgrade of MIT's sewerage system.
- Implementation planned to minimize disruption to vehicle and pedestrian traffic on and across Mass Avenue, a major arterial road in Cambridge.

Managing the Transition from Construction to Operation: Sub-Tasks

- Sub-Tasks depend upon type of project
- Buildings: prepare space for occupancy by tenants
- Transportation: prepare procedure for safe opening of new facility

Managing the Transition from Construction to Operation: Potential Pitfalls

- Marketing plan may be upset by a bad economy or major world events:
 - Panama Canal opened on first day of WW I
 - Empire State Building opened in depths of Great Depression
- Failure of design
 - Spectacular failure of Tacoma Narrows Bridge
 - Need to replace windows of Hancock Building in Boston
- Failure in operation:
 - Automated baggage control system at Denver International Airport failed to function properly when the airport first opened

Project Completion: Sub-Tasks

- Finishing touches and corrections
- Finances: sell or re-finance
- Turn over all responsibility to new owners or operating managers

Project Completion: Potential Pitfalls

- Lack of demand:
 - Many condominium complexes were built in expectation of an ever-rising market, but were in fact completed after the collapse of the real estate market in 2008; thousands of condos remained vacant for years.
- Public resistance prevents operation:
 - The Shoreham Nuclear Power Plant on Long Island was completed and eventually approved for operation, but never opened because of intense local opposition.

Assessing or Auditing the Project: Sub-Tasks

- Evaluation of the construction process
 - Safely completed on time and on budget?
- Evaluation of the construction design
 - Was this an effective design?
- Evaluation of the project with respect to its goals
 - Did the project actually meet its original financial, social, or environmental goals?

Assessing or Auditing Projects: Potential Pitfalls

- Materials may turn out to be hazardous
 - Use of asbestos for insulation
- Failure to provide protection may lead to fatalities
 - Failure to provide safety nets for construction of bridges or tall buildings
- Environmental impacts may be extreme
 - Reliance on auto has led to massive problems related to safety, emissions and land use
- Design may turn out to be inappropriate
 - Public housing projects in St. Louis were demolished after only 20 years

Project Management Techniques

- Statement of work
- Work breakdown structure
- Network diagrams
- Schedules
- Budgets

Statement of Work

- Part of the contractual agreement between the owner and the builder or the basic objective for the project manager
- What is to be done, using what resources, within what timetable
- Changes to the statement of work may be needed:
 - Owner: change in scope of project
 - Contractors: changes in costs, time or processes may be needed
 - Trade-off: time required to complete project vs. cost of completion

Statement of Work: Basis for Initial Estimates

- Past experience
 - Just another fast food restaurant, or a typical railroad siding, or another modest office building
- Self-confidence
 - Eiffel Tower – based upon use of same materials to build bridges
- Careful planning
 - Dams, space stations and other projects requiring special technology and careful attention to the site

Work Breakdown Structure (WBS)

- Break down a complex project into manageable activities
- Identify and categorize all of the steps that will be required
- Can be shown as a table or as an organizational chart

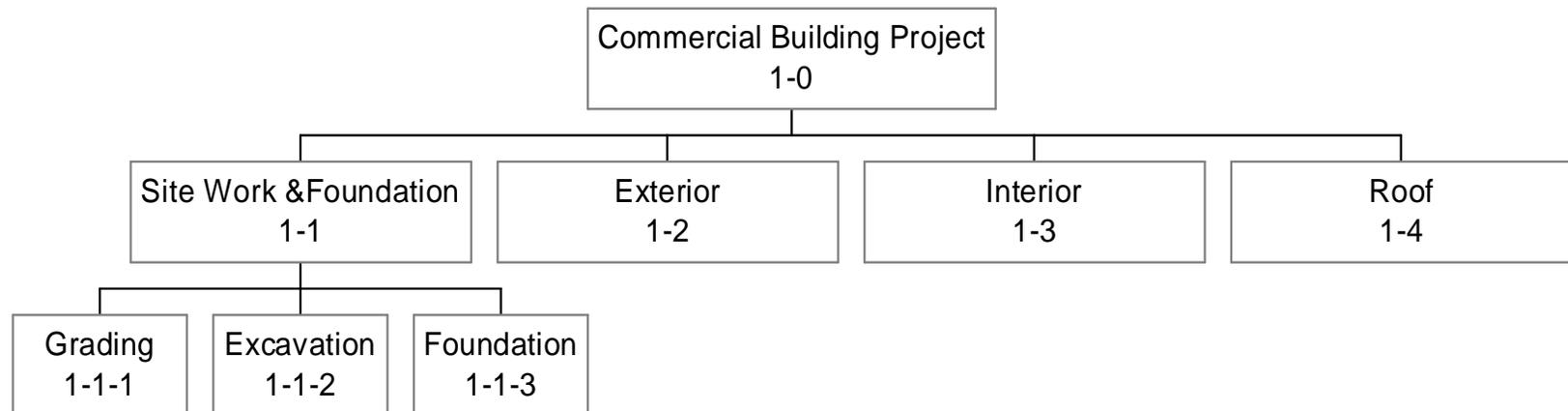
Work Breakdown Structure

- Top-down description of the project
- Functional and physical elements
- Mutually exclusive, collectively exhaustive description of the work elements

Goal:

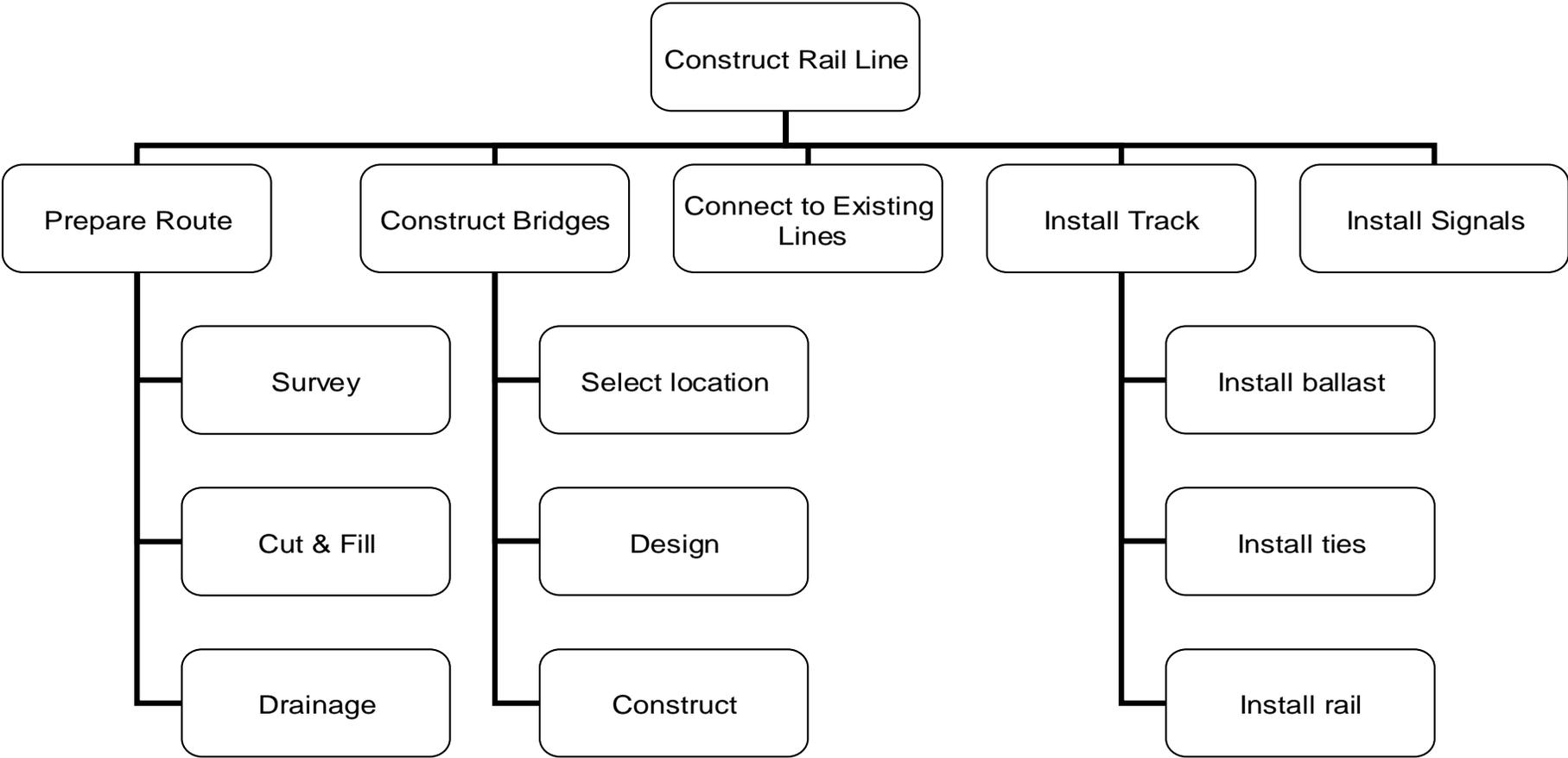
A logical structure that can be used at any level of analysis related to estimating the cost of a project

Work Breakdown Structure (Partial)



Break the work into segments for which there is a clear and logical way to assign costs.

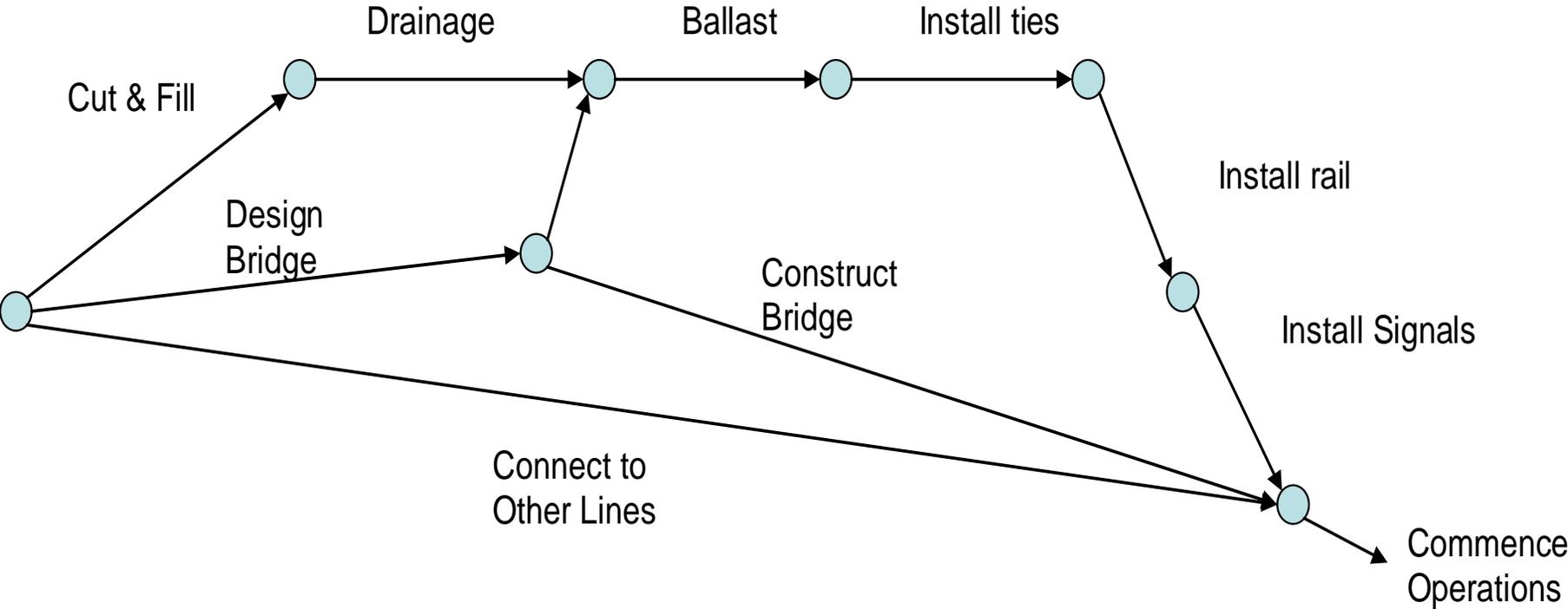
WBS for Constructing a New Rail Line



Network Diagram

- Show how the activities in the WBS are related
- Some activities can start immediately; others must wait until prerequisite activities are completed
- Interdependencies among activities may reflect logic, regulations, choice of technology or contractor preferences

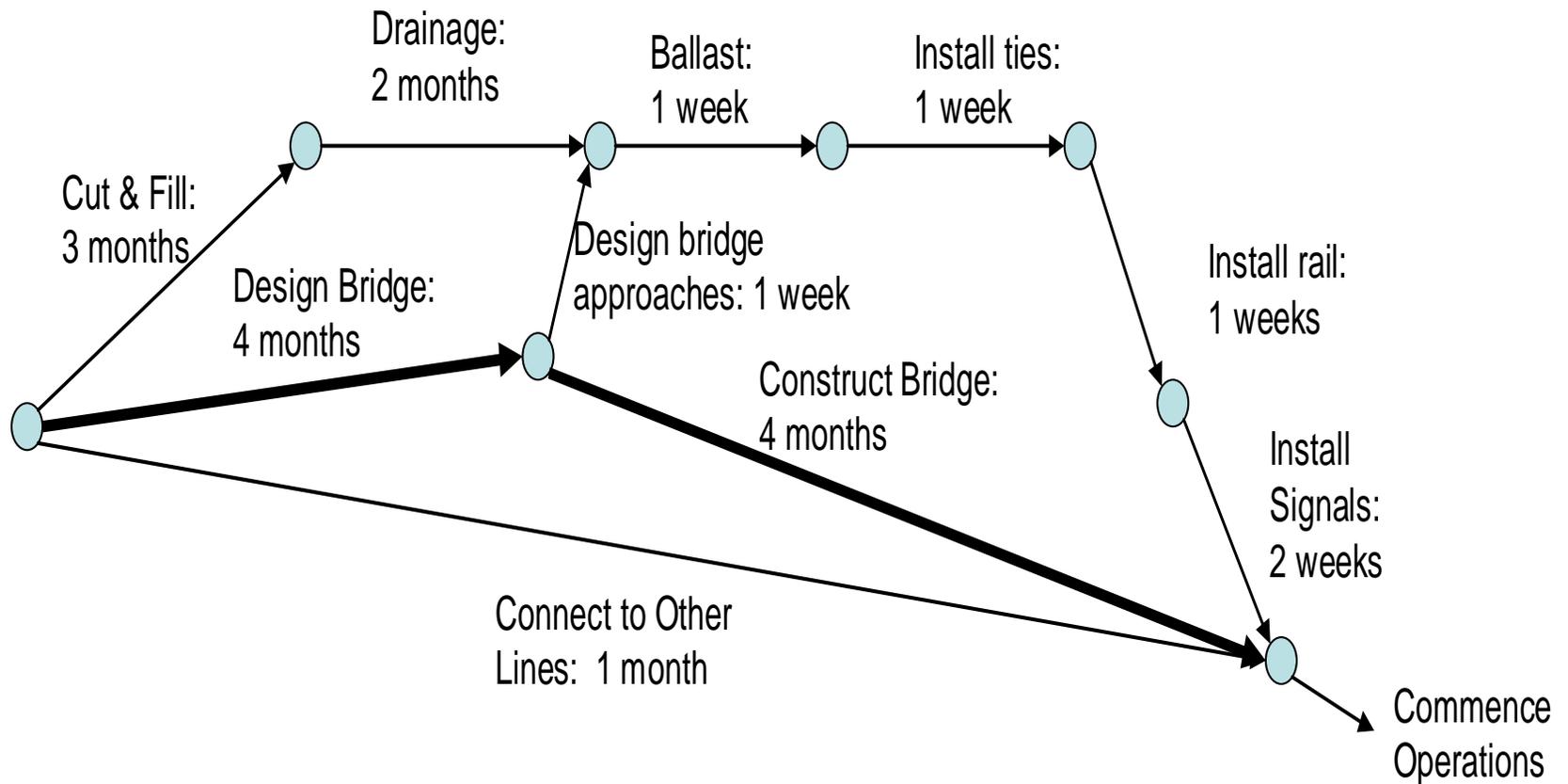
Network Diagram for a New Rail Line



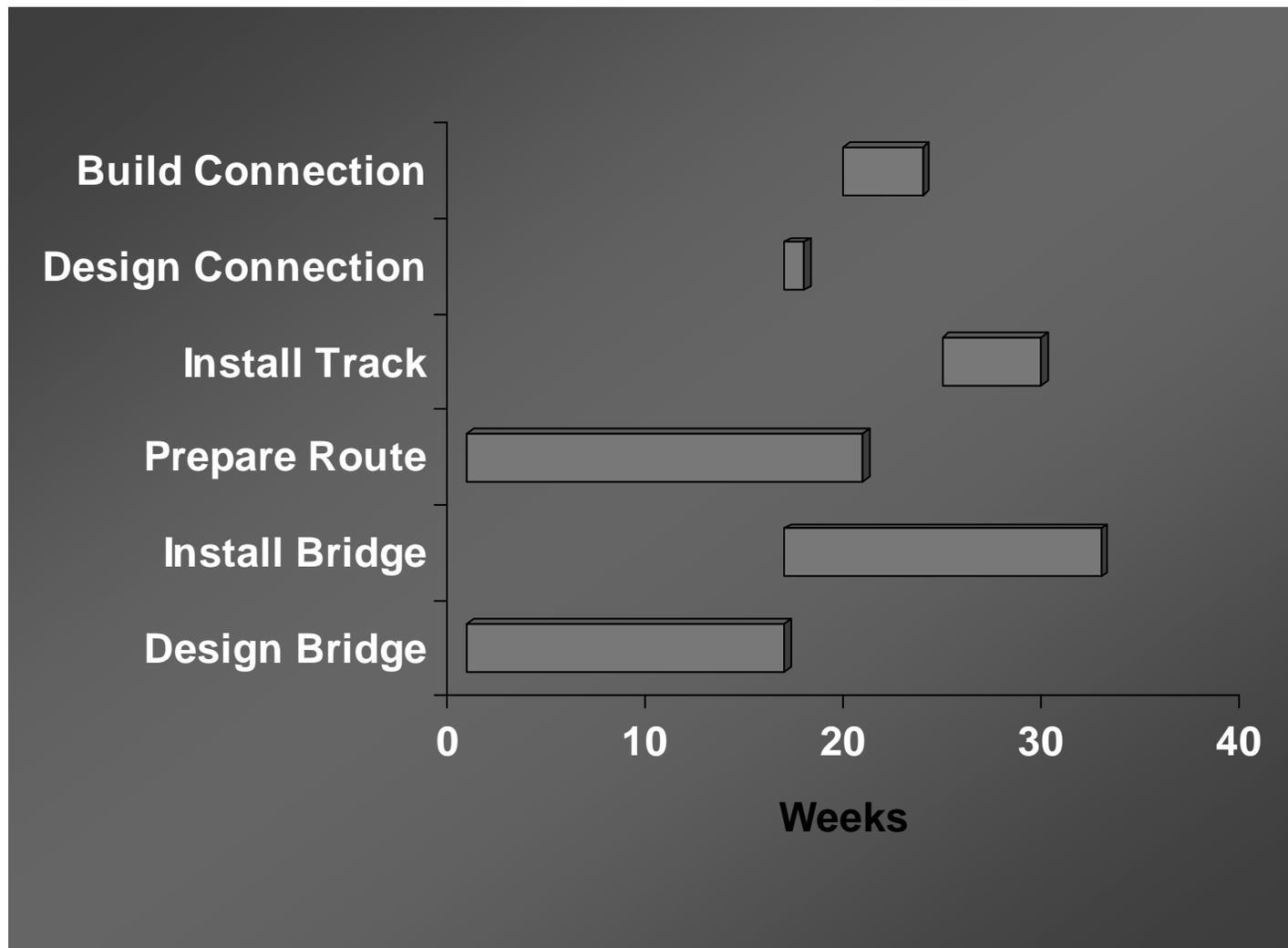
Schedules for Activities

- Earliest start date
- Latest start date
- Critical path of activities (the minimum time for completion of the project)
- Slack time
 - The difference between the earliest and latest start date for an activity
 - Equals zero for activities on the critical path

Critical Path for the Railroad Project



Task Schedule for Construction of a New Rail Line



Linear Responsibility Chart

- List all activities
- Identify all people involved in managing project
- Indicate who plays what role for each activity
- Review responsibilities with each manager
- Revise and repeat as necessary until the chart is understood and accepted by everyone
- Review and update as needed

Linear Responsibility Chart for Construction of a New Rail Line

Task	Project Manager	Assistant Chief Engineer - Design		Leader, Route Preparation Gang	Leader, Track Gang	Leader, Bridge Gang
		Design	Field			
Design Connection	A	P				
Build Connection	A		P		S	
Install Track	A		P		S	
Prepare Route	A		P	S		
Design Bridge	A	P				
Install Bridge	A		P			S
Logistics	P	S	S			

A – Approval Authority; P – Primary Responsibility; S – Secondary Responsibility

Linear Responsibility Chart: Details for Installing Track

Task	Project Manager	Leader, Track Gang	Office of the Assistant Chief Engineer - Field		Leader, Ballast	Leader, Ties	Leader, Rail
			Purchasing	Personnel			
Purchase Materials	A		P				
Transport Materials to Site	A		P	S			
Lease Equipment	A		P				
Assemble track Gang	A	S		P	S	S	S
Install Ballast		P			S		
Install Ties		P				S	
Install Rail		P					S

Estimating Resource Requirements

- How many people will be needed for each task?
- How long will it take them to complete each task?
- How many tasks can they complete each day and each week?
- How much material will be needed?

Estimating Resource Requirements: 19th Century Rail Gang

Task Number	Task Name	Gang Size	Time Required
1	Position tie plate and spikes	2 men	5 minutes
2	Spike tie plates	4 men	5 minutes
3	Place rail	50 men	5 minutes
4	Spike rail	4 men	5 minutes
5	Attach joint bars	2 men	15 minutes
Total		62 men	35 minutes

Plan A for the 62-Man Gang: 16 Rails per Day

Time Interval	1 st Rail	2 nd Rail	3 rd Rail	4 th Rail	5 th Rail	6 th Rail	7 th Rail
0-5 min.	1						
5-10	2						
10-15	3	1					
15-20	4	2					
20-25	5	3	1				
25-30	5	4	2				
30-35	5		3				
35-40		5	4	1			
40-45		5		2			
45-50		5		3	1		
50-55			5	4	2		
55-60			5		3	1	

Increasing delays are introduced because it takes so long for Task 5

Modifying the Work Schedule

- Problem: 16 rails per day means that it would take far too long to complete the job
- Plan B:
 - Have a few men come in early to position all the tie plates for the day's work (Task 1)
 - Have a few men start spiking tie plates before the main gang arrives (Task 2)
 - Put more men to work on anchor bars (Task 5), which was the task holding up progress.

Plan B: 48 Rails per Day

Time	1 st Rail	2 nd Rail	3 rd Rail	4 th Rail	5 th Rail	6 th Rail	7 th Rail
Early Work	1,2	1,2	1,2	1,2	1,2	1,2	1,2
0-5	3						
5-10	4	3					
10-15	5a	4	3				
15-20	5a	5b	4	3			
20-25	5a	5b		4	3		
25-30		5b	5a		4	3	
30-35			5a	5b		4	3
35-40			5a	5b			4
40-45				5b	5a		
45-50					5a	5b	

Further Increases in Productivity

- Assign a third team to Task 5 in order to eliminate all of the delays
 - 80 rails per day
- Assign another gang to start from the other end of the new route:
 - 160 rails per day
- Provide some mechanical assistance in moving the rail, so that it wouldn't take 50 men to do the job (Task 3); small gangs could then do more work in one day

The Modern Process is Highly Mechanised



Cost Estimation and Budgets

- Rough estimates will be sufficient at first
 - Cost estimates that are accurate only to +/- 30-40% will likely still be better than estimates of possible benefits or the costs of financing
 - Overlooking costs is more likely to be a problem than mis-estimating costs
 - Rules-of-thumb are commonly used
- More accurate costs will be needed as the number of options dwindles, but +/- 10-15% will be OK
- Eventually, once the project is approved, a budget should be accurate to within a few percent

Sources of Information

- Internal to firm or agency
 - Accounting system & historical records
 - Special studies
- External
 - Expert opinion
 - Published data (e.g. industry cost studies)
- Special Studies
 - R&D
 - Comparison with prior studies

Expert Opinion

- Comprehensive perspective on range of costs
- Sophisticated Work Breakdown Structure
- Experience and Understanding
 - Cost drivers and unit costs
 - Potential problems – and how to deal with them
 - Contacts and comparisons re: similar projects

Costing Using WBS: Creating Rules of Thumb

- Obtain unit costs for all elements and activities required to construct a particular type of structure (e.g. excavation, floor coverings, walls, windows, or roofing)
- Design a “model” structure (e.g. an 8-story office building, with 12-foot stories, and 100,000 SF of floor space)
- Count the total units required for the model structure and calculate the cost/SF of floor space
- Use these costs/SF as estimates for similar buildings

Estimates of Unit Costs for Constructing an Office Building

Task	Unit	Unit Cost	Cost/SF of Building
1-1-2 Excavation and preparation for slab	Sq. Ft. of ground	\$1.10	\$0.14
1-2-1 Exterior walls, pre-cast concrete panels (80%)	SF of wall	\$17.59	\$6.08
1-2-2 Windows (20%)	Each	\$375	\$2.16
1-3-6 Floor Finishes – 60% carpet; 40% tile	SF of floor	\$5.02	\$5.02
1-4-1 Roof covering – tar & gravel with flashings	SF of roof	\$2.32	\$0.29

Add it all up to get a total cost/SF for the “model”

Source: RS Means, “Square Foot Costs 2000”

Costs per Square Foot of Floor Area for 5-10 Story Office Buildings

Exterior Wall	Square Feet Area	50,000	60,000	70,000	80,000	90,000	100,000
	Linear Feet Perimeter	328	370	378	410	441	450
Precast Concrete Panel	Steel Frame	\$92.45	\$92.75	\$88.20	\$87.10	\$86.20	\$85.85
	Reinforced Concrete Frame	\$92.85	\$92.15	\$89.55	\$88.45	\$87.55	\$86.20

Source: RS Means, "Square Foot Costs 2000"

Costs per Square Foot of Floor Area for 5-10 Story Office Buildings

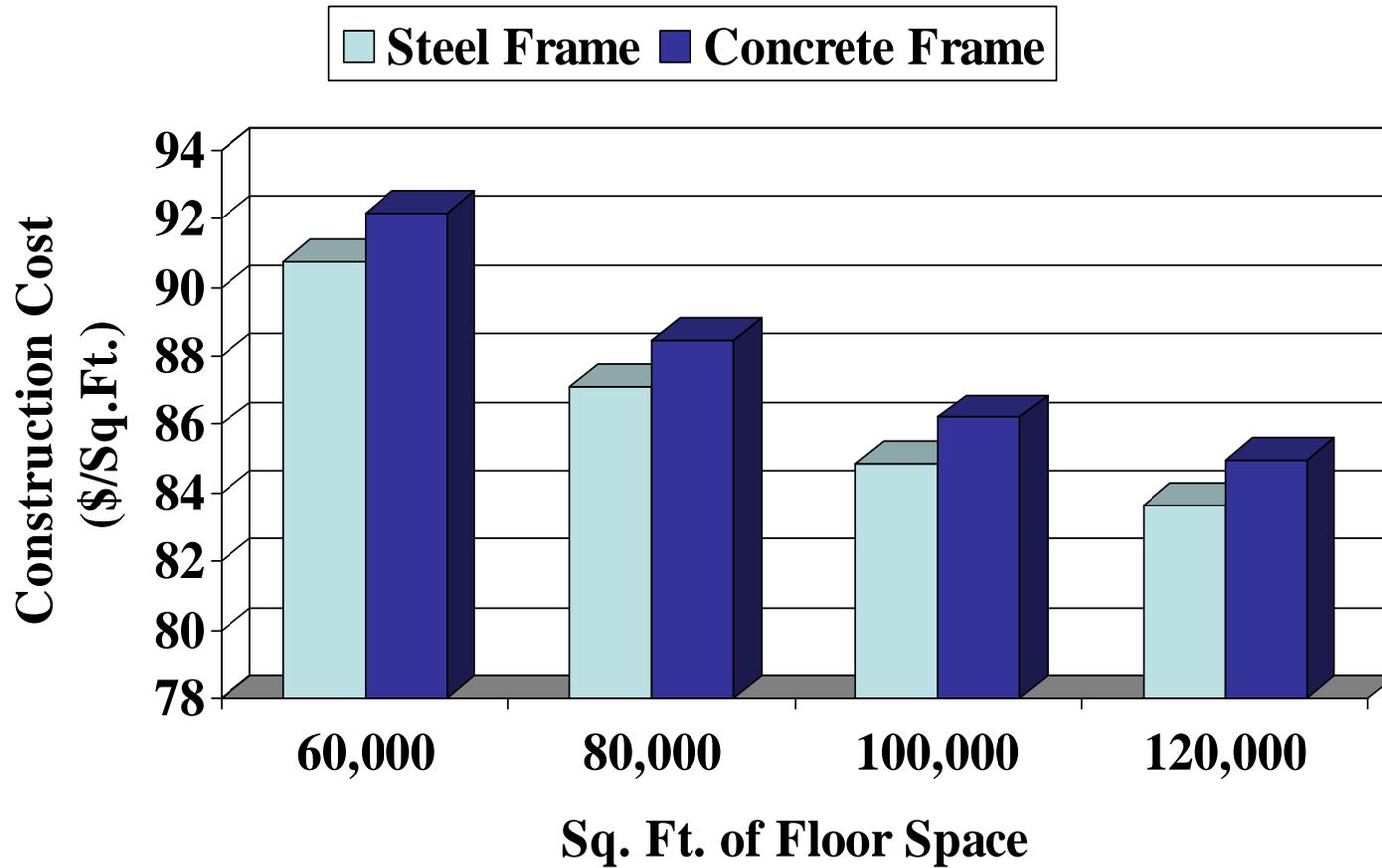
Ext Wa	A steel frame building with 100,000 SF of space would be estimated to cost \$85.85 per SF for a total of \$8.6 million						100,000	100,000
							441	450
Precast Concrete Panel	Steel Frame	\$92.45	\$92.75	\$88.20	\$87.10	\$86.20	\$85.85	
	Reinforced Concrete Frame	\$92.85	\$92.15	\$89.55	\$88.45	\$87.55	\$86.20	

Source: RS Means, "Square Foot Costs 2000"

Total Cost/SF, Various Office Buildings

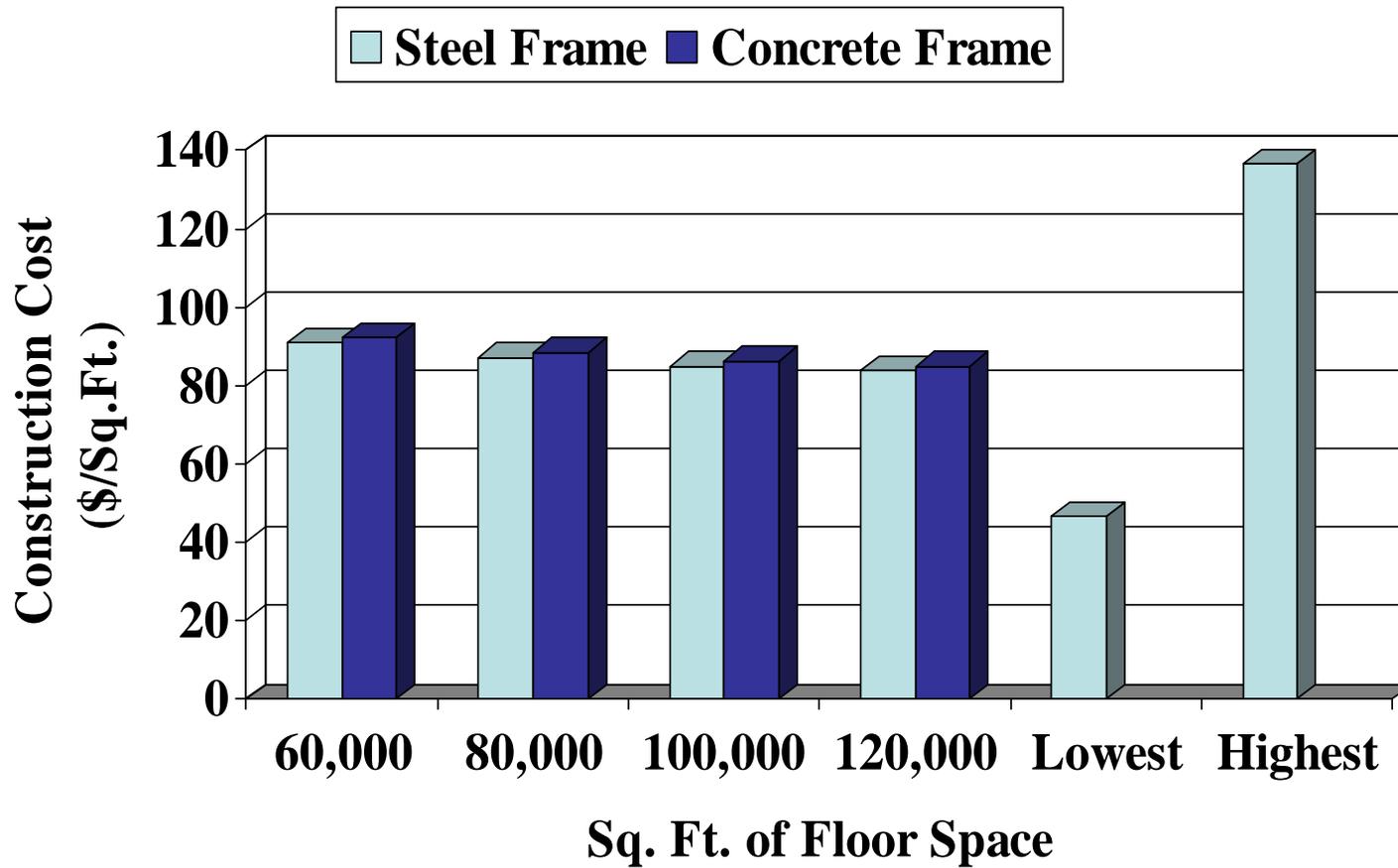
Model: 8-stories, each 12' high, 100,000 SF floor area

(Source: RS Means, "Square Foot Costs 2000")



Total Cost/SF, Various Office Buildings and the reported range for recently completed projects

(Source: RS Means, "Square Foot Costs 2000")



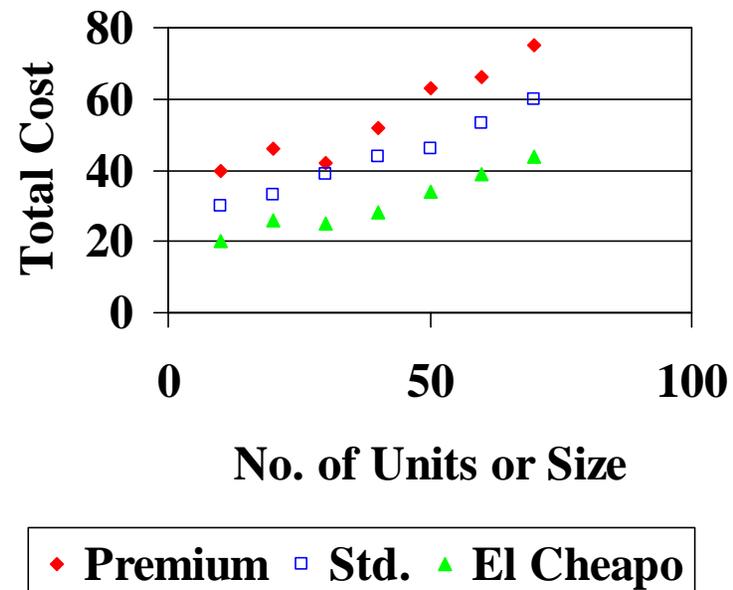
Using Past Experience to Estimate Costs

- Past experience is useful, and statistical techniques can be used to estimate cost models
- It is necessary to adjust past experience for:
 - Inflation
 - Economies of Scale (e.g. power sizing)
 - Experience (i.e. the learning curve)

Statistical Techniques

- **Data:** cost for similar projects
- **Analysis:** regression analysis
- **Model:** relate cost to key variables using reasonable functional form

Cost as a Function of Size



Adjusting for Inflation

Estimating current cost C(0) as a function of past cost C(P):

$$C(0) = C(P) \left(\frac{\text{Current cost index}}{\text{cost index year P}} \right)$$

Estimating future costs C(F) as a function of current cost C(0):

$$C(F) = C(0) (1 + \text{Expected Inflation})$$

Adjusting Costs for Inflation: given actual costs from 1981 to 2009, predict costs for a similar project in 2010 as the average of the current \$ costs

Year of Project	Actual Cost	Cost Index (1981 = 100)	Current \$ Cost (2009 dollars)	Future \$ Cost (2010 dollars)
1981	\$70 thousand	88.3	\$221 thousand	\$227 thousand
1985	\$80	116.6	\$191	\$197
1997	\$130	167.6	\$216	\$222
2001	\$160	195.0	\$228	\$235
2004	\$170	219.9	\$215	\$222
2009	\$200	278.3	\$200	\$206
2010		278.3 (1.03)	\$212	\$218

Power-Sizing

We can relate costs of new project (or of a work element or of a component) to costs of a similar one of a different size, if we know there is a clear relationship between size and cost

Cost is proportional to (Size)^b

Cost A/Cost B = (Size A/Size B)^b

Where b is based upon statistical analysis, physics, standards or expert opinion

Example: Power Sizing

	Size of Project (Base Case = 100)						
b	50	75	100	150	200	500	1000
0.6	66	84	100	128	152	263	398
0.8	57	79	100	138	174	362	631
1.0	50	75	100	150	200	500	1000
1.2	44	71	100	163	230	690	1585
1.4	38	67	100	176	264	952	2512

Learning Curve

CEE projects are not generally mass-produced, so it may not be possible to start with the most efficient construction approach. A company will likely learn to do things better as they build more projects.

Common assumption: costs decline by constant factor when output doubles:

1st project: cost = K

2nd project: cost = $K*s$, where $0 < s < 1$

4th project: cost = $(K*s)*s$

8th project: cost = $(K*s*s)*s$

We can use an estimate (guess?) for the learning rate “s” to determine the cost of the Nth project or of the first N projects.

Effect of Learning Curve on the Cost of a Project (Base Cost = 100)

Repetitions	Doublings	98%	97%	95%	90%	85%	80%	75%
1	0	100	100	100	100	100	100	100
2	1	98	97	95	90	85	80	75
4	2	96	94	90	81	72	64	56
8	3	94	91	86	73	61	51	42
16	4	92	89	81	66	52	41	32
32	5	90	86	77	59	44	33	24
64	6	89	83	74	53	38	26	18
128	7	87	81	70	48	32	21	13
256	8	85	78	66	43	27	17	10
512	9	83	76	63	39	23	13	8
1024	10	82	74	60	35	20	11	6

Learning Curve Example

- Bidding on a project to strengthen 8 bridges
 - Estimated cost of first bridge: \$1 million
 - Estimated learning curve: 90%
- Estimate costs for three bridges directly from the table:
 - Cost of second bridge: \$0.9 million
 - Cost of fourth bridge: \$0.81 million
 - Cost of eighth bridge: \$0.73 million
- Interpolate to get the costs for the other bridges:
 - Cost of third bridge: approx. \$0.85 million
 - Cost of bridges 5,6, and 7: approx. \$0.77 million each
- Total for eight bridges: \$6.6 million (versus \$8 million if there were no benefit from the learning curve)

Including Overhead Expenses

- Overhead includes expenses that are not directly associated with any project, such as:
 - Administration
 - Marketing
 - Office expenses
 - Property taxes
- Economists recommend pursuing projects if revenues will make some contribution to overhead and profit
- Accountants generally apportion overhead to projects based upon rules (which may be arbitrary and illogical):
 - Overhead = $X\%$ of project costs
 - Overhead = $Y\%$ of salaries plus $Z\%$ of other costs

Traditional Structure for a Public Project

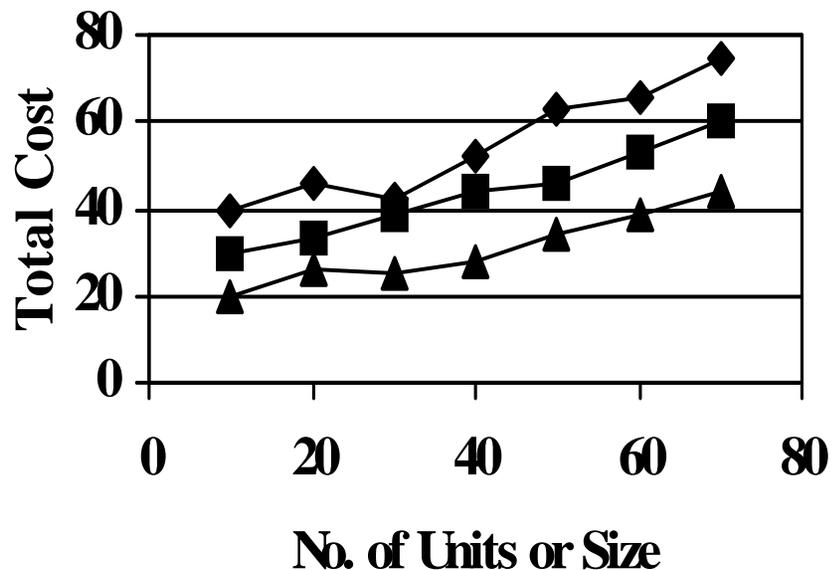
- Design competition
 - Request submission of conceptual designs
- Selection of best concept and contract with winner to prepare final design
- Competitive bidding for the construction job
- Select contractor or general contractor
- Supervise contractor as construction proceeds
- Upon completion, public agency manages operations

Keys to Effective Cost Estimation

- Use common sense
 - Spend time on the “cost drivers”
 - Create a logical cost structure
- Use mathematics
 - Simple to sophisticated, as required
- Provide a reasonable level of detail
- Use parameters (variables, not constants) for unit costs, productivity, size, and performance
- Be organized, consistent and careful

Using Common Sense to Create a Simple Cost Model: Basic Cost Information

Constant \$ Costs for Completed Apartment Buildings



—◆— Premium —■— Std. —▲— Budget

Expert Judgment

1. Data seem to show a linear relationship
2. Quality should be a multiplier
3. Past projects each had their own quirks that need not be included in the model

Using Common Sense to Create a Simple Cost Model: Structuring the Model

1. Developer's judgment determines the model structure:

$$TC = (FC + \text{Cost/Unit} * \text{Units})(\text{Quality Factor})$$

2. Past experience provides estimates of FC and VC

$$FC = \$20 \text{ million}$$

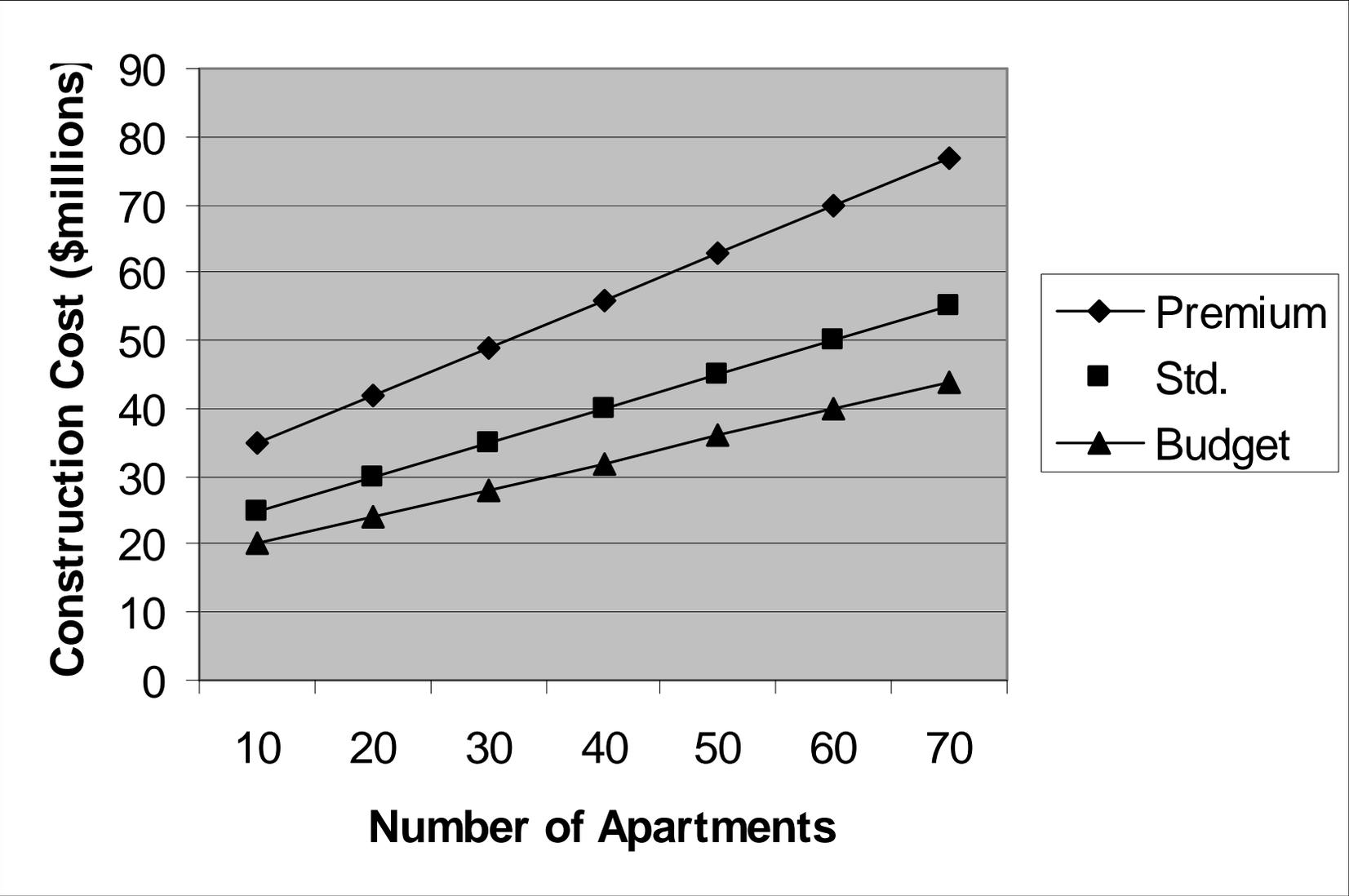
$$VC = \$0.5 \text{ million per unit}$$

3. An approximate quality factor will be fine:

Premium 140% of standard

Lowest quality units: 80% of standard

Using Common Sense to Create a Simple Cost Model: A Simple, Easily Used Model



Organizational Structure

- Three broad phases in the life of a project:
 - Design
 - Build
 - Operate
- These phases can be managed by a single company or public agency or by different companies or agencies

Problems with the Traditional Approach

- There is a disconnect among the various stages of the project:
 - Designers may not be concerned with the costs of construction or operations
 - Construction firms may not worry about the life cycle costs of operations and maintenance
 - There is little opportunity for synergism, so that the design may not reflect the expertise of contractors or the needs of operators
- The public agency may not have the expertise to operate the facility when it is completed
- The public agency may not be able to finance the facility

Other Approaches

- Design/Build (DB)
 - The same company designs and constructs the project
- Design/Build/Operate (DBO)
 - The same company also operates the facility
- Design/Build/Operate/Transfer (DBOT)
 - Operation of the facility is transferred back to the public agency after a specified number of years

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