1.040/1.401
Project Management
Spring 2007

Project Organization Part I
Delivery Systems

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Department of Civil and Environmental Engineering
Massachusetts Institute of Technology
Project Management Phase

- Feasibility Development
- Design Planning
- Estimating
- Risk
- Organization
- Planning

- Development
- Closeout
- Operations
Outline

- **Project Participants**
  - The Owner
    - The Design Team
    - The Construction Team

- **Project Delivery Systems (Most Common)**
  - Traditional
  - Pure Construction Management
  - Construction Management at Risk
  - Design / Build
  - Combination – Build / Operate / Transfer
  - Summary
The Owner: Internal Structure

- **Capital Projects Officer:** Strategic Planning
- **Financial Officer:** Financial Planning
- **Owner’s Project Manager:** Tactical Level Supervision
- **Owner’s Inspector:** Operational Decisions
- **End Users:** Directly or Indirectly Represented

Source: Peña-Mora et al., 2004
The Owner

- **Typical Interest**
  - To achieve an efficient product delivery mechanism with a simple structure of responsibility
    - reduce schedule and cost, increase quality, reduce claims, increase innovation and constructability, and increase flexibility in both their capital investment and the construction process)

- **Perfect Owner?**
  - The one whose only requirement is some respect for the budget
  - The one that knows exactly what needs to be done and how
Public & Private Owners

- **Public Owners**
  - State, Municipal or Federal Government, DoD, DoE
  - Usually Large Projects
  - Very Well-Defined Procedures
  - Careful Project Financing (Political accountability)

- **Private Owners**
  - Ranging from Real Estate Developers to One-Time Projects
  - Usually Smaller Projects (occasionally Larger Projects also)
  - More Informal Procedures
  - Usually More Innovation, Cost-Efficiency and Flexibility
Public-Private Partnerships

- Hybrid Owner From Contractor’s and User’s Viewpoint

- Basic Modes (and Variations):
  - Gov’t Contracts Operations & Maintenance of Existing Facility with a Private Entity
  - Gov’t Sells a Facility to the Private Sector
  - Gov’t Contracts a Company to Build-Operate-Transfer a Project
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The Design Team

- The Architect
  - 1st Contact of the Owner
  - Usually in Contract with the Owner
  - Selected by “Competition” Based on Qualifications or Selected based on Personal Preferences
  - Fiduciary Relationship in which one party, the owner, places special trust, confidence, and reliance in and is influenced by another (the architect) & vice versa

- The Engineering Team
  - Structural / Transportation / Geotechnical Engineer
  - Usually Subcontracts (or Houses)
    - Environmental Engineers
    - Mechanical Engineers
    - Electrical Engineers
The Architect - Example

- **Cesar Pelli & Associates Architects**
  - Established in 1977
  - Estimated number of employees: 80
  - Works with corporate, governmental & private clients
  - Designs public spaces, museums, airports, laboratories, performing art centers, academic buildings, hotels, office & residential towers

- **Awards**
  - AIA 1989 Firm Award
  - AIA 1995 Gold Medal Award

- **Signature projects**
  - Petronas Towers – Kuala Lumpur, Malaysia
  - Citi Group Tower – London, UK
  - Visit website on [www.cesar-pelli.com](http://www.cesar-pelli.com) for complete list of projects

Photograph removed due to copyright restrictions.
The Engineering Team - Example

Parsons

- Established in 1944
- 100% employee owned engineering & construction company
- Estimated number of employees: 9,000
- Delivers design-build projects to governmental & private clients
- Specializes in: Aviation, bridges & tunnels, commercial & industrial facilities, education & healthcare buildings, environmental structures, roads & highways, rails & transit

Landmark projects

- Baiyun International Airport – Guangzhou, China
- Pierce County Tacoma Narrows Bridge – Washington, USA
- Dominican Republic National Strategic Master Plan for Construction – Dominican Republic

Baiyun International Airport
- Covering 13.5 square km (8.38 square miles)
- Capable of handling 25 million passengers and 186,000 aircraft operations annually

Visit website on [www.parsons.com](http://www.parsons.com) for complete list of projects

Source: [www.parsons.com](http://www.parsons.com)
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The Construction Team: The Contractor’s Project Manager

- Oversees Entire Project but Mainly Deals with:
  - Owner Relations
  - Schedule
  - Claims
  - Cost and Budget Issues
  - Major Engineering Issues related to Construction
  - Subcontractor Issues
  - Safety
  - Quality Control
## The Construction Team:

**Estimator**

- **Quantity Take Off**

### Formwork For Beams

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<th>Item</th>
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</table>

- **Error & Omissions are typical in quantity take-off’s, but they cost real money**
The Construction Team:
Scheduler

- Produces and Maintains Job Schedule with the Help of the Engineers and Superintendents
- Early Involvement in the Project
- Dealing with Multiple Interfaces (Owner, Designer, Superintendents)
- Excellent Understanding of the Construction Technology and Technique Behind the Schedule
- Continuously Modifying the Schedule
The Construction Team:
Scheduler Work Product

Screenshot removed due to copyright restrictions.
The Construction Team: Superintendent

- **General Superintendent**
  - Oversees All Operations of Building the Project
  - Coordinates Subcontractors and Various Field Superintendents
  - Deals with Craft Unions
The Construction Team: Superintendent

- Field (i.e., Assistant) Superintendent
  - Oversee Their Specific Field (i.e., expertise) Operations (e.g., Utility, Earth Support, Concrete, Mechanical, Equipment)
  - Direct the Crews that Work in This Area
  - In Charge of:
    - Time Sheets
    - Scheduling
    - Planning
    - Safety
    - Quality Control
    - Subcontractors
The Construction Team: Engineer

- **Project Engineer**
  - Oversee All Engineering and Administration Functions of the Project
  - Work closely together with project manager
  - In Charge of:
    - Owner Relations
    - Submittals, RFI’s, Changes
      - Leads problem identification, definition, analysis, solution generation, solution implementation and pay requirements
    - Claims
    - Cost Control
    - Subcontractors
The Construction Team: Engineer

- Field Engineer
  - Daily Reports of Activities
  - Measure Quantities of Work Completed
  - Help Superintendents with Planning and Ordering Permanent Materials
The Construction Team: Engineer

- Resident Engineer
  - The Owners Representative on the Job Site
  - Makes the Decisions for the Owner and the Owners Engineer
The term refers only to the contractual arrangement not to the scope of work.

- Company X performs 2 contracts; one for Owner A and the other for Contractor B.

- Contractual obligation to the original contractor not the owner.
## Responsibility Matrix

### Table:

<table>
<thead>
<tr>
<th>Position</th>
<th>President</th>
<th>Secretary-Treasurer</th>
<th>Vice President</th>
<th>Accountant</th>
<th>Paymaster</th>
<th>Cost Clerk</th>
<th>Purchasing Agent</th>
<th>Asst Purchasing Agent</th>
<th>Expediter</th>
<th>Chief Estimator</th>
<th>Cost Estimator</th>
<th>Takeoff Engineer</th>
<th>Operations Manager</th>
<th>Project Manager</th>
<th>Equipment Superintendent</th>
<th>Warehouse Person</th>
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</tbody>
</table>

**Legend:**
- **O** - Originator; does the work
- **R** - Must review
- **A**- Must approve
- **I** - Must be informed or advised

*Source: Clough et al., 2005*
Outline

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Traditional Design Bid Build

- Hire a Design Professional in Charge of the Preparation of the Design and Contract Documents
- Usually Competitive Bid or Negotiation with Contractors
- Contractor in Charge of the Delivery of the Completed Project (May Decide to Subcontract)
- The Contractor is the Only One Responsible of the Execution of the Work
Traditional Design Bid Build

- Sequential Construction Process

- Lump Sum Bid Commonly Adopted whereby Owner assigns Project Risks to the Contractor: built-in adversarial relationship

- Trust-based Collaborative Relationship between A/E (Chosen on Qualification Basis) and Owner

- Different Participants’ Interests:
  - Owner: Quality and Value Product, Delivery Schedule, Site Safety
  - Contractor: Profit, Construction Time, Relationships, Reputation
  - A/E: Profit, Aesthetics, Relationships, Quality, Recognition
Advantages of the Traditional Method

- Well Known Method
- Cost Already Defined
- Good Contractual Protection for the Owner
- Owner Not too Involved in the actual Construction Process
Disadvantages of the Traditional Method

- Generally, Design not Reviewed for Constructability Before Construction (i.e., contractor’s small role in the design phase)
- Sequential and Linear Process which Prevents Task Overlapping and Implementation of Time & Money Saving Strategies
- Few Interactions among the Participants
- Construction can’t Start until Design is Complete
Campus Recreation Center East, UIUC

- Groundbreaking: October 2003
- Facility Opened: March, 2005
- Architect: VOA Associates Inc.
- General Contractor: William Brothers Construction, Inc.
- Cost: $22 million
- New additions and renovations include 110,000 sq. ft of activity space
- Aquatic center with temp. controlled pool, waterslide and waterfall
- 3 court gymnasium
- 1/8 th mile, 3 lane track

Source: http://www.acta.org

Photographs removed due to copyright restrictions.
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Pure Construction Management

Source: Peña-Mora et al., 2002
The Owner hires, based on qualifications, both a Design Firm and a Construction Management Firm before the beginning of the construction of the Project.
Pure Construction Management

- Owner in Fiduciary Relationship with the PCM
- PCM as Facilitator/Mediator in Conflicts
- PCM Generally Paid a Fixed Fee
Advantages of Pure CM

- One Trusted Common Reference Point for Construction: The CM
- Great Flexibility in the Schedule
- Great Flexibility for Changes
- Small Financial Risks for PCM
Disadvantages of Pure CM

- Participants Must All Be Cooperative and have Open Communication
- All Parties Must Be Committed from the Beginning
- Small Incentive for CM (they get paid anyway)
- High Risk of Loss of Reputation
Central Artery / Big Dig

Photograph of elevated Central Artery removed due to copyright restrictions.

Source: http://www.bigdig.com
Central Artery / Big Dig

- Most Complex Highway Project in American History at that time
- The Project Consists of Building 161 Lane Miles of Urban Highway – About Half Underground in a 7.5-Mile Corridor
- Planning for the Central Artery/Tunnel Project Began in 1982
- Congress Approved Funding and the Project's Basic Scope in April 1987
- Estimated Cost: $14.624 Billion
- Section Design consultants: 100
- The CA/T Consists of 118 Separate Construction Projects & 26 Geotechnical Drilling Contracts
- During Peak of Construction (1999-2002):
  - Work Completed per Day: $3 Million
  - Workers on Job Site: 5,000

Source: http://www.bigdig.com
MTA - Massachusetts Turnpike Authority

B/PB – Joint venture of Bechtel & Parsons Brinkerhoff

Source: http://www.bigdig.com
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Construction Management at Risk

Owner

C/M

Contractual Relationship

Trade contractor

A/E

Communicational Relationship

Trade contractor

Trade contractor

Source: Peña-Mora et al., 2002
Construction Management at Risk

- Contractual Relationships between CM and Trade Contractors
- CM usually Guaranteeing Maximum Price (GMP) to Give the Owner Security that the Project Will Be Built within Budget
Advantages CM at Risk

- Reduced Owner’s Risk for Construction
Disadvantages CM at Risk

- Owner takes responsibility for design defects / omissions
- Owner may not have full control on contract changes as desired
- The GMP is A Defined Price for An Undefined Product

Source: CII, 1997
Albert and Barrie Zesiger Sports and Fitness Center, MIT

- Groundbreaking: October 2000
- Occupancy: 2002
- Designed by the Architectural Firms of Roche & Dinkeloo and Sasaki Associates
- CM @ Risk: Turner Construction Co.
- Cost: $45 million
- Olympic-class 50-meter pool
- An 11,000-square-foot Fitness Center

Source: http://web.mit.edu/evolving/projects/zesiger

Photograph removed due to copyright restrictions.
Albert and Barrie Zesiger Sports and Fitness Center, MIT

Owner
MIT

A/E
Kevin Roche-John Dinkeloo & Associates

Contractual Relationship

CM @ Risk
Turner Construction

Trade Contractor

Trade Contractor

Trade Contractor

Contractual Relationship

Communicational Relationship

Source: http://web.mit.edu/evolving/projects/zesiger
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  ➤ Design / Build
    ▪ Combination – Build / Operate / Transfer
    ▪ Summary
Design-Build

Owner

Construction Function

D/B Entity

Design Function

Sub contractor

Sub contractor

Sub contractor

Source: Peña-Mora et al., 2002
The Owner hires a Design/Build Firm that will complete both Design and Construction.

This firm can be a Design/Build Firm but also a Joint-Venture Firm of a Design Firm & Construction Firm for this specific project.

The Design/Build Firm hires subcontractors.
Design-Build

- One Contractual Team Responsible for Design and Construction Function
- Owners put More Emphasis on Schedule
- Owner with Enough Knowledge about Design and Construction to Establish the Initial Parameters, Review Proposals and Monitor the Process
Advantages of DB

- Allows fast tracking
- Good interactions among Design & Construction participants
- Easier incorporation of changes in most cases
- Good for complex projects
Disadvantages of DB

- Pricing isn’t possible at the beginning
- Risk of sacrificing quality to protect profit
- May take a direction that the Owner does not really want
- Lack of checks and balances
Alameda Corridor

- A 20-mile Railroad Expressline that Connects the Ports of Los Angeles and Long Beach, CA
- Construction Schedule: 1997-2002
- Estimated Cost: $2.4 Billion
- Alameda Corridor Transportation Authority Governing Board Constituted of Seven Members
- The Alameda Corridor Consists of 25 Construction Projects

Source: http://www.acta.org

Map and photograph removed due to copyright restrictions.
Modified CM Design/Build: Design Subcontracted

Modified CM Design/Build
(CM Serves as Design/Builder and Subcontract Design)

Source: Potter, 1995
CM Oversight Design/Build

CM Oversight Design/Build
(CM Provides Agency Oversight on Owner’s Behalf)

OWNER

DESIGN/BUILD CONTRACTOR

CM

SUB-CONTRACTOR

SUB-CONTRACTOR

SUB-CONTRACTOR

SUB-CONTRACTOR

Source: Potter, 1995
Outline

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Combination – Build/Operate/Transfer

- Facility financed, designed, built, and operated by a private developer
- Legal way to “lease” to a concessionaire for a fixed time period
- Government-owned/government-built facilities
- Concession that at the completion of the concession period, the facility is “returned” to the original owner (government agency)
- The government may guarantee a level of service & pay if it is short
- Either agreed-upon price or as payment for the concession
- Designed to take advantage of lower cost or “tax free” funding provided by governments
The Channel Tunnel, England-France

- A 50 Km undersea / underground tunnel connecting England to France
- Infrastructure consists of two main tunnels and one service tunnel (located in the center)
- Estimated Cost (1987 Dollars): $9.1 Billion
- Actual Cost on Completion (1994 Dollars): $21 Billion
- Eurotunnel, a consortium of Channel Tunnel Group (British Contractor) and France Manche (French Contractor) is the owner and operator of the channel
- The English Channel Consists of Multiple Construction Projects

Source: Winch, 1998
Figures by MIT OCW.
The Channel Tunnel, England-France

Source: Winch, 1998

Figure by MIT OCW.
Outline

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➢ Summary
Four Main Delivery Systems:
Relationships Between Participants

1. **Traditional Design-Bid-Build**
   - Owner
   - General Contractor
   - A/E
   - Subcontractor
   - Trade contractor
   - C/M

2. **Construction Management at Risk**
   - Owner
   - C/M
   - A/E
   - Subcontractor
   - Trade contractor
   - Competition Function

3. **Pure or Agency Construction Management**
   - Owner
   - C/M
   - A/E
   - Trade contractor

4. **Design-Build**
   - Owner
   - D/B Entity
   - Design Function
   - Subcontractor

Source: Peña-Mora et al., 2002
## Advantages of the 3 Most Common Delivery Methods

<table>
<thead>
<tr>
<th>Type of contracts</th>
<th>Traditional Approach</th>
<th>Design Build</th>
<th>Construction Management</th>
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<td>Fast-tracked construction allowed</td>
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<td>Minimum owner involvement</td>
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<td>Cost benefit from competition</td>
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</tr>
<tr>
<td>Negotiation with quality contractor for unique expertise</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Allow adjustment to new conditions without changing agreement</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Single firm control of design/construct process</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Adapted from: Gould & Joyce, 2003
# Disadvantages of the 3 Most Common Delivery Methods

<table>
<thead>
<tr>
<th>Type of contracts</th>
<th>Traditional Approach</th>
<th>Design Build</th>
<th>Construction Management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disadvantages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design does not benefit from construction expertise</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design construction time is the longest</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adversarial relationship owner/designer vs contractor</td>
<td>X</td>
<td>~X</td>
<td></td>
</tr>
<tr>
<td>Contract agreement affected by changes</td>
<td>X</td>
<td>~X</td>
<td></td>
</tr>
<tr>
<td>Few checks and balances</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Cost control occurs late in project</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Contract amount may be complicated by continual contractor negotiations</td>
<td>X</td>
<td>~X</td>
<td></td>
</tr>
<tr>
<td>Contract agreement affected by unforeseen conditions</td>
<td>X</td>
<td>~X</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from: Gould & Joyce, 2003
CM @ Risk, DB, & DBB - Comparison

- Study conducted by CII (Construction Industry Institute) on 350 construction projects
- Provides industry with considerations to aid in delivery method selection
- Key project data for projects under a certain delivery system were collected. These include:
  - Design & construction cost growth
  - Design & construction schedule growth
  - Construction Speed (Sq. Ft./Month)
  - Quality / Turnover: startup difficulty, call backs, operations & maintenance

Adapted from: CII, 1997
**CM @ Risk, DB, & DBB - Comparison**

- **Design & construction cost growth**
  
  \[\text{Design & construction cost growth} = 100 \times \frac{\text{Final Project Cost} - \text{Contract Award Cost}}{\text{Contract Award Cost}}\]

- DBB has highest cost growth at **4.83** percent
- DB has lowest cost growth at **2.17** percent

- **Design & construction schedule growth**
  
  \[\text{Design & construction schedule growth} = 100 \times \frac{\text{Total As Built Time} - \text{Total As Planned Time}}{\text{Total As Planned Time}}\]

- DBB has highest schedule growth at **4.4** percent
- DB & CM@R have zero schedule growth

*Figure by MIT OCW.*

*Adapted from: CII, 1997*
**Construction Speed (Sq. Ft./Month) = [Area / (Total As Built Time in Days/30)]**

- DB & CM@R have median in 8,000 to 9,000 square feet per month
- DBB has median in 5,000 to 5,500 square feet per month

Adapted from: CII, 1997
**CM @ Risk, DB, & DBB - Comparison**

- Quality / Turnover (after construction): startup difficulty, call backs, operations & maintenance
- Responses are sought with great objectivity
- Responses are from facility owners
- Quality is represented on a scale of 1 to 10
- Higher scores represent lower difficulty in start-up & fewer call backs
- DBB provides least quality level

<table>
<thead>
<tr>
<th></th>
<th>DBB</th>
<th>DB</th>
<th>CM@R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality - Turnover, Start-up Difficulty</td>
<td>6</td>
<td>7.5</td>
<td>7.43</td>
</tr>
<tr>
<td>Quality - Turnover, Call Backs</td>
<td>7</td>
<td>7.9</td>
<td>8.1</td>
</tr>
<tr>
<td>Quality - Turnover, Operations and Maintenance</td>
<td>6.9</td>
<td>7.7</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Figure by MIT OCW. Adapted from: CII, 1997