Market Trends – A Focus on Engineering Productivity

Dean P. Findley
May 29, 2008
Purpose

• Share information on recent market trends
• Discuss one area of market bottleneck: Engineering
• Provide recommendations for avoiding the bottleneck
Outline

• Introducing IPA

• The Setting

• Market Trends

• Engineering Productivity

• Conclusions
Independent Project Analysis

• IPA independently measures the performance of capital projects for a variety of companies

• Devoted to the analysis of capital projects as a field of empirical research

• We measure the Leading Indicators:
  – Front-End Loading (Project definition)
  – Team Effectiveness
  – Use of Value Improving Practices

• We help owners set and achieve goals

• IPA improves the competitiveness of its customers by helping them use capital more effectively
How Does IPA Help Improve Capital Projects?

- **Data**
  - 10,000+ Projects
  - 850+ Companies
  - Varying project types
  - Over 2,000 Variables per project

- **Empirical Research**
  - Statistical Analysis
    - Practices vs. Results
    - Project research

- **Transfer and Exchange of Knowledge**
  - Performance and Plans
    - Best Practices
    - Benchmarks
IPA Works at Several Levels

- *Individual projects* form the foundation of our work
- Diagnosing (benchmarking) *project systems* provides companies with the basis for improvement
- *Benchmarking Conferences* bring companies together to share practices and metrics
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 a.m.-9:15 a.m.</td>
<td>Welcome</td>
<td>Belmont Ballroom</td>
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<tr>
<td>9:15 a.m.-10:00 a.m.</td>
<td>Keynote Address</td>
<td>Belmont Ballroom</td>
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<tr>
<td>10:00 a.m.-10:15 a.m.</td>
<td>Break</td>
<td>Belmont Foyer</td>
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<tr>
<td>10:15 a.m.-10:30 a.m.</td>
<td>Safety Metrics</td>
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<td>10:30 a.m.-12:00 p.m.</td>
<td>Industry Metrics</td>
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<tr>
<td>12:00 p.m.-1:00 p.m.</td>
<td>Lunch</td>
<td>Potomac Ballroom/Colvin Run</td>
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<tr>
<td>1:00 p.m.-2:00 p.m.</td>
<td>Operability</td>
<td>Belmont Ballroom</td>
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<tr>
<td>2:00 p.m.-3:00 p.m.</td>
<td>Market Trends- Engineering Productivity</td>
<td>Belmont Ballroom</td>
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<tr>
<td>3:00 p.m.-3:15 p.m.</td>
<td>Break</td>
<td>Belmont Ballroom</td>
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<td>Time</td>
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<td>9:00 a.m.-9:15 a.m.</td>
<td>Agenda Overview</td>
<td>[Belmont Ballroom]</td>
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<tr>
<td>9:15 a.m.-10:15 a.m.</td>
<td>Peer Reviews and Capital Effectiveness</td>
<td>[Belmont Ballroom]</td>
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<tr>
<td>10:15 a.m.-10:30 a.m.</td>
<td>Break</td>
<td>[Belmont Foyer]</td>
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<tr>
<td>10:30 a.m.-11:30 a.m.</td>
<td>Defending the Gate: Examining Gatekeeping in a Stage-Gated Project Definition Process</td>
<td>[Belmont Ballroom]</td>
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<td>11:30 a.m.-12:30 p.m.</td>
<td>Best and Worst IBC 2008 Projects</td>
<td>[Belmont Ballroom]</td>
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<tr>
<td>12:30 p.m.-1:30 p.m.</td>
<td>Lunch</td>
<td>[Potomac Ballroom/Colvin Run]</td>
</tr>
<tr>
<td>1:30 p.m.-2:30 p.m.</td>
<td>Presentation by Alcoa</td>
<td>[Belmont I &amp; II]</td>
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<tr>
<td>2:45 p.m.-3:30 p.m.</td>
<td>Commercialization of Alternative Energy Technologies</td>
<td>[Belmont Foyer]</td>
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<td>3:30 p.m.-4:00 p.m.</td>
<td>Company Breakouts</td>
<td>[As Assigned]</td>
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<td>4:00 p.m.-4:45 p.m.</td>
<td>Commercialization of Alternative Energy Technologies</td>
<td>[Belmont I &amp; II]</td>
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<td>4:45 p.m.-5:00 p.m.</td>
<td>Closing Remarks</td>
<td>[Belmont I, II, &amp; III]</td>
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<td>5:00 p.m.-6:00 p.m.</td>
<td>IBC Steering Committee Meeting</td>
<td>[Sully]</td>
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<td>6:00 p.m.-7:00 p.m.</td>
<td>Reception // Welcome Small Projects and Site Systems</td>
<td>[Belmont Foyer]</td>
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</table>
Outline

• Introducing IPA

• The Setting

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• Engineering Productivity

• Conclusions
The Projects Crisis

- We are in our 5th year of the first world-wide projects crisis in the process industries
- Barring a global economic slowdown, the crisis has years to run
- On-going and near-term spending is unprecedented
  - $1.4 trillion in Middle East alone
  - 55 projects > $100MM in Alberta
  - $400+ billion on USGC
  - Etc...
- This is no longer any fun
Harsh Reality

The cupboard is empty:

• Many equipment items have escalated 80 percent in the past few years and delivery times have lengthened

• Engineering shortages are spreading from all of the major engineering centers to the value centers

• Lack of FEL resources is causing a dramatic slowing of project development

• Labor shortages combined with other problems have created a growing series of project “hotspots”
Regional Hotspots

- Australia
- Western Canada
- USGC
- Brazil
- Middle East
- West Africa

Next?
Issues

• How is the crisis playing out?

• How much damage will be done to
  – projects?
  – capital project systems?
  – companies’ futures?

• How will we respond?
Project Casualties are Mounting

- More projects are spinning out of control
- Large projects are especially vulnerable
- Projects are slowing dramatically, but not by choice and therefore not by plan
- Quality, especially engineering quality, is suffering
Causes of Failure

- Most failed projects are old-fashioned business objectives and FEL failures
- Even relatively small errors are severely punished in the current market
- However, we are seeing more genuine execution failures, an expected but new result
When Projects Fail...

The Scapegoats Must be Found!

- Six IBC companies have replaced their heads of engineering with contractor executives with no prior owner experience.

- We are seeing several reorganizations.

15 years of progress is in jeopardy.
What Needs to be Done?

• At the Corporate Level?

• At the Project System Level?
Corporate Level

- Business education
- Trimming of the portfolio
- Capability assessment
Ground Business Management in Reality

• If your management does not understand the basics of capital projects and how business actions control capital projects, it is education time!

• If your management does not appreciate the state of the project markets and its implications, it is education time!

• If you cannot find somebody or some way of getting them to listen, dust off your résumé
Trim the Portfolio

• We continue to work on too many projects

• Trim the portfolio of:
  – economically marginal projects
  – vampire projects
  – projects bogged down in regulatory, political or partner problems
  – projects for which the technology is not ready

• Control of the portfolio is essential, especially in decentralized companies
Assess Project Capabilities

- Inventory project staffing resources across the company
- Account for increasing attrition
- Account for the (in)effectiveness of new hires
- Provide management with a realistic assessment of how many you can develop and execute as a function of project size and complexity
Project System Level Actions

• In addition to being ever more scrupulous with the fundamentals, you need to explicitly plan to cover contractor deficiencies in
  – Design QA/QC
  – Construction QA/QC
  – Expediting and inspection of vendor-supplied materials
  – Construction management
  – Project cost and schedule controls

• Suggesting that many of these are contractor responsibilities is true but a waste of time
Market Trends
A Focus on Engineering Productivity

Dean P. Findley and Luke M. Wallace
Outline

- **Market Trends**
- Engineering Productivity Database
- Drivers of Engineering Productivity
- Time Trends and Regional Differences
- Conclusions
Capital Spending Has Increased in All Industries

For Example, Global Chemical Spending

Source: Chemical Engineering, January 2008
Where Is the Spending Increase Happening?
2006 to 2009 Period

Share of incremental gain in 2006-2009 capital spending

North America: 6%
Latin America: 2%
Asia-Pacific: 58%
Western Europe: 17%
Emerging Europe: 4%
Africa and Middle East: 13%
New Technology Projects Have Declined

But, We Expect an Increase

![Graph showing the percentage of projects in the IPA database with one or more new process steps from 1990 to 2008. The percentage has declined from 20% in 1990 to around 5% in 2008. There is a note that an increase is expected.]
Megaproject Activity Has Significantly Increased

% Projects > $250MM
% Projects > $500MM

Authorization Year

Percentage of Large Projects Collected by IPA

Demographic Trends

Labor Force Is Aging in Many Developed Regions

Source: U.S. Bureau of Labor Statistics
U.S. Engineers: Fewer Young People and Sharp Decline After Age 54

Source: U.S. Bureau of Labor Statistics
Engineering Degrees by Country

Source: National Science Foundation, Science & Engineering Indicators, 2006
Putting the Trends in Context

• Demand has never been greater:
  – China and other developing nations are growing
  – Commodity prices (oil, metals, etc.) are all relatively high
  – More “megaprojects” to capture economies of scale

• Market’s ability to expand is constrained
  – Demographic challenges
  – Years of downsizing and contractor consolidation
  – Vendors do not quickly expand production
  – Construction labor reflects the region (e.g., Alberta versus China)
Supply and Demand for Capital Projects

*The Market Cannot Respond Quickly*
Supply and Demand for Capital Projects
A Short-Run View of the Problem

[Graph showing supply and demand curves for capital projects]
Prices Have Increased A LOT!!

- Varies by cost element
- Varies by project type
- Varies by location
- Not just the increase—the volatility
Cost escalation trends are displayed in US dollars.
Major Equipment Cost Escalation Varies by Type of Equipment

Data are a composite escalation index for various types of projects
Cost escalation trends are displayed in U.S. dollars
Construction Labor Escalation
Varies by Location

Cost escalation trends are displayed in local currency.
Escalation Varies by Project Type

Data are a composite escalation index for various types of projects
Cost escalation trends are displayed in U.S. dollars
• Markets do not adjust instantly
  – Price changes in current period are related to changes in previous period
  – Specific markets are affected by external events, but an adjustment lag usually occurs
  – Understanding the adjustment lags is basis for short-run predictions

• Longer term forecasts require predictions of the external events (GDP, megaprojects, oil price, etc.)
  – More difficult
  – Adds to uncertainty
Forecast Price Sensitivity
-- An Example With Megaproject Activity --

Price Index (Jan. 2003 = 100)

Year

2008 2009 2010 2011 2012

Base Forecast
% Mega (Decreasing)
% Mega (Constant)
Forecast Price Sensitivity
-- An Example With Metal Prices --

Price Index (Jan. 2003 = 100)

Year

2008 2009 2010 2011 2012

Base Forecast
Metal Price (Constant)
Metal Price (Decreasing)
Market Trends Summary

Productive Engineers Are Critical

• Market activity has increased – more projects, bigger projects, complex projects
• Costs have increased and become more volatile for many locations, project types, and cost elements
• The market trends are not likely to quickly change
• Demographic challenges are substantial, especially among the highly skilled
• Engineering is a bottleneck—how are we going to debottleneck the system?
Why Should We Care?
Because Engineering Is Highly Leveraging

- **Absolute Performance**—Engineering services is often the category that determines overall performance

- **Predictability**—Engineering overruns by more than any other cost category (21 percent, on average)

- **Operability**—Problems executing the design are the immediate cause of field problems, delayed startups, and operability issues
Engineering Productivity Matters

10% Improved Engineering Productivity

- 2% Lower Cost
- 3% Faster Project
- 5% Better Operability

Delta Internal Rate of Return

Base Case

Projects With 10% Better Engineering Productivity

- Cost Impact
- Schedule Impact
- Production Attainment Impact

Independent Project Analysis 2008
Outline

• Market Trends

• Engineering Productivity Database

• Drivers of Engineering Productivity

• Time Trends and Regional Differences

• Conclusions
### Updated Engineering Productivity Database

**More Projects, More Current**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Projects</td>
<td>992</td>
</tr>
<tr>
<td>Estimated Project Cost (in millions of US$)</td>
<td>$111 / $24 (mean/median)</td>
</tr>
<tr>
<td><strong>Range of Total Project Costs</strong></td>
<td>$4 million to $6 billion</td>
</tr>
<tr>
<td>Average Authorization Year</td>
<td>2004</td>
</tr>
<tr>
<td><strong>Range of Authorization Years</strong></td>
<td>1995 to 2008</td>
</tr>
<tr>
<td>Number of Owners Represented</td>
<td>132</td>
</tr>
<tr>
<td>Number of Engineering Contractors Represented</td>
<td>200+</td>
</tr>
<tr>
<td>Percentage of Projects With New Technology</td>
<td>6 percent</td>
</tr>
</tbody>
</table>
Engineering Productivity Database

Industry Breakdown

- Refining: 39%
- Chemicals: 36%
- Metal & Minerals Processing: 10%
- Pharmaceuticals: 6%
Geographical Distribution of the Projects

- North America: 54%
- Canada: 5%
- South America: 5%
- South Africa: 3%
- Middle East: 3%
- Oceania: 5%
- Europe: 18%
- Asia: 7%
- South Africa: 3%
- Middle East: 3%
Development of an Engineering Index

Inherent Factors

- Size
- Process Complexity
- New Technology
- Project Type
- Estimates

Predicted Engineering Hours
Detailed Engineering Hours

Rule of Thumb: About 1 Hour for Every $1,000

- High Complexity Process
- Low Complexity Process

P < 0.0001
Engineering Productivity Index
Engineering Productivity Varies Within and Across Industries

Industries

- Refining
- Com. Chem
- Special Chem
- Forest
- Pharms
- Cons. Products
- Metals/Minerals
- Pipelines

Engineering Productivity Index
Engineering Productivity Varies Within and Across Companies

IBC Companies
Industry and Company Differences

• Variance in engineering productivity is substantial

• What are the practices that improve productivity?

• Then we will consider regional differences and time trends
Outline

• Market Trends

• Engineering Productivity Database

• *Drivers of Engineering Productivity*

• Time Trends and Regional Differences

• Conclusions
Front-End Loading (FEL) Improves Productivity

DRIVERS OF PRODUCTIVITY

- FEL Strategies
- Schedule Strategies
- Teams & Other

Pr < 0.01
FEL Components

- A few specific FEL items are disproportionately important to engineering productivity
  - Basic data items, such as heat and material balances (H&MBs), process control strategy, and instrumentation requirements
  - Site-related issues
    > Various environmental requirements
    > Utilities, especially waste treatment needs
Overlapping FEL and Detailed Engineering Reduces Productivity

**Drivers of Productivity**
- FEL Strategies
- Schedule Strategies
- Teams & Other

![Graph showing the relationship between overlap of FEL and engineering and productivity index.](graph.png)

Pr < 0.07
Overlapping Engineering and Construction Reduces Productivity

DRIVERS OF PRODUCTIVITY

- FEL Strategies
- Schedule Strategies
- Teams & Other

Pr < 0.04
Formally Defined Roles and Responsibilities Is Key

Drivers of Productivity

- FEL Strategies
- Schedule Strategies
- Teams & Other

Pr < 0.024

Engineering Productivity Index

- Std. Dev.  + Std. Dev.
Project Experience Matters

DRIVERS OF PRODUCTIVITY

- FEL Strategies
- Schedule Strategies
- Teams & Other

![Graph showing the relationship between similar projects by engineering lead and engineering productivity index, with a trend line indicating a decrease as the number of similar projects increases, and a significance level of Pr < 0.04.]

Independent Project Analysis 2008
Good Project Control Yields Better Productivity

**DRIVERS OF PRODUCTIVITY**

- FEL Strategies
- Schedule Strategies
- *Teams & Other*

![Graph showing the relationship between Project Control Index and Engineering Productivity Index. The x-axis represents the Project Control Index ranging from 0.90 to 1.15, and the y-axis represents the Engineering Productivity Index ranging from 0.90 to 1.15. The graph shows a positive correlation between the two indices, with labels for GOOD, FAIR, and POOR performance levels. The inset text indicates that the statistical significance is Pr < 0.057.]
Key Practices Remain Fundamental

- **Best Practical FEL**
  - Projects achieving *Best Practical FEL* average a 0.95 productivity index

- **Overlap**
  - Overlapping less than 10 percent of the execution duration results in competitive productivity

- **Teams**
  - Teams with formally defined roles and responsibilities are 15 percent more productive

- **Project Controls**
  - To achieve competitive productivity, project controls need to be at a *Good* level
Related Issues and Previous Research

A Few Comments

- **Automated design tools**
  - Initial use versus ongoing improvements

- **Incentivized contracts do not work**

- **Engineering value centers**
  - Increasing use, but generally less productive with lower wages
  - Direct owner connection improves total project value

- **Thinly staffed project teams**
  - Large owner teams set the basis for good performance
  - Staff key positions with owner staff

- **Local content requirements**
  - Increasing issue, especially in less developed regions
  - More on this later
Outline

• Market Trends

• Engineering Productivity Database

• Drivers of Engineering Productivity

• *Time Trends and Regional Differences*

• Conclusions
Geographical Distribution of Engineering Locations

- US: 55%
- Canada: 7%
- South America: 5%
- South Africa: 2%
- Europe: 21%
- Asia: 5%
- Oceania: 5%
Productivity Varies by Region
Engineering Productivity Has Recently Declined, And Is Likely Getting Even Worse
FEL Varies by Engineering Region

- US
- Canada
- Europe
- Asia
- Australia
- South America

FEL Index:
- BEST
- GOOD
- FAIR
- POOR
- SCREENING

In Independent Project Analysis 2008
FEL Is More Important in “Hot Spots”

Engineering Productivity Index vs. Front-End Loading Index

- Europe
- US
- S. America
- Asia
- Australia
- Canada

Screening levels:
- BEST
- GOOD
- FAIR
- POOR
- SCREENING

Hot Spots where FEL is more important:
Outline

• Market Trends

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• Time Trends and Regional Differences

• Conclusions
Conclusions—Trends and Practices

- Market trends are not going away
  - Capital spending will remain high
  - Labor markets present the greatest challenge

- Engineering productivity is critical

- Best Practices remain essential:
  - FEL is a prerequisite and avoid extensive overlaps
  - Team alignment is important, along with experience, continuity, and project controls
Conclusions—What About the Regions?

• Mature Project Regions:
  – **Strengths:** Project fundamentals provide a foundation
  – **Opportunities:** Reduce the variance in applying Best Practices and recover from years of downsizing

• Emerging Project Regions:
  – **Strengths:** Economic growth and labor is generally available
  – **Opportunities:** Project fundamentals must be improved and training is necessary
We are in it for the long term!

- Use the current market opportunity to establish and/or rebuild owner competence
- Locate engineering centers in favorable markets
- Do not authorize fundamentally weak practices

10 percent better productivity means 10 percent fewer engineers to achieve better outcomes!