Framing the issues

• Engineering drives construction productivity

• The front-end drives engineering

• Teams drive the front-end

• Objectives drive the teams

• Conclusions
Industrial construction in the United States and OECD is suffering from a slow and insidious productivity crisis.

While productivity in manufacturing in OECD has improved, productivity in construction has actually declined over the last two decades.

The hope is that advanced work packaging and better workface planning can be part of an effort to turn the situation around.

But for far too many projects, and especially large complex projects, construction work package improvement is won’t make much difference.

When the field is a chaotic mess, the problems that created mess are almost never in the field.
Some Questions

• How do we end up with so many projects with very poor construction productivity?

• What are the proximate causes?

• What are the root causes?

• Why has improvement been so difficult to sustain?
### Onshore Projects Database Employed

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Projects</td>
<td>3,278</td>
</tr>
<tr>
<td>Average Project Cost (2015 USGC$*)</td>
<td>$324 million</td>
</tr>
<tr>
<td>Range of Total Project Cost</td>
<td>$15 million to $35 billion</td>
</tr>
<tr>
<td>Average Authorization Year</td>
<td>2007</td>
</tr>
<tr>
<td>Range</td>
<td>2000 to 2014</td>
</tr>
<tr>
<td>Execution Duration</td>
<td>23 months</td>
</tr>
<tr>
<td>Range</td>
<td>10 months to 44 months</td>
</tr>
<tr>
<td>Cycle Time</td>
<td>39 months</td>
</tr>
<tr>
<td>Range</td>
<td>16 months to 76 months</td>
</tr>
<tr>
<td>Number of Owners Represented</td>
<td>180</td>
</tr>
</tbody>
</table>

* USGC = U.S. Gulf Coast
Projects

Industry Sector Distribution

- Refining: 28%
- Chemicals: 30%
- Mining: 7%
- Pharmaceuticals: 7%
- Consumer Products: 12%
- Pipelines: 7%
- Other: 9%
Geographical Distribution of Projects

- North America: 44%
- South America: 9%
- Africa: 5%
- Europe: 18%
- Middle East: 6%
- Asia: 9%
- Oceania: 6%
- CIS: 2%
- Mexico & Caribbean: 2%
- South America: 9%
• Framing the issues

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Engineering Drives Procurement and Field Labor Productivity

Big Drivers of Field Labor Productivity:

- The availability of engineered materials
- The availability of accurate design

Design and materials are made available → Successful projects (Even with some of the world’s poorest labor)

Design and materials are not made available → World’s best labor using the best workface planning will generate pathetic labor productivity
When Engineering Slips

Materials procurement is late and out of sequence for construction

IFC design is insufficient to start work in the field, but field start occurs anyway, especially with EPC contracting

Design quality starts to plummet as the review cycle and QC are under stress

Labor productivity is very poor

The project collapses in the field
Engineering Error Rate Affects Field Labor Productivity

Pr < 0.009

Controlled for Multiple Factors
Engineering Slip Drives Field Productivity

Field Labor Hours Growth

Engineering Slip

Pr < 0.0001
Engineering Slipping Around the World

Average Slip in Detailed Engineering

- Australia
- Alberta
- Africa
- USA
- Asia
- Europe
Slipped Engineering Is the New Normal

Results controlled for level of engineering definition, occurrence of late changes, PM turnover, and project size
When Engineering Slips

Materials procurement is late and out of sequence for construction

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So what causes engineering to slip?
• Framing the issues
• Engineering drives construction productivity

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Drivers of Engineering Slip

- **FEED is not P&ID Complete**
- **Major Design Changes**
- **Owner Team Turnovers**
- **Cash Flow Constraints**

9 to 18 Percent Added Slip  Pr. <.001

Each Major Change +6 percent  Pr. <.0001

Each Turnover +7 Percent  Pr. <.0001

+12 Percent  Pr. <.01

*The Engineering is Seriously Late*
Design Changes Drive Engineering Slip

But Not All Changes are Equal

Source of the Change:
- Engineering
- Team
- Business
- Operations

Effect of Each Major Change on Engineering Slip:
- Engineering: 6%
- Team: 4%
- Business: 4%
- Operations: 8%
Owner Team Turnovers Add to Engineering Slip

But Not All Turnovers are Equal!

Position Replaced

- Project Mgr
- Lead Engg
- Cons Mgr
- Operations

Effect of Owner Team Turnovers on Engg Slip

- 12%
- 10%
- 8%
- 6%
- 4%
- 2%
- 0%
When front-end work is not completed:

- The first task after authorization is completing FEED, often 2 to 4 months.
- Because resource-loaded engineering schedules were not developed, our understanding of the number of hours by discipline is not clear.
- Errors in FEED are not uncovered during FEED because the P&IDs were not complete so hazards analysis is not done.
- Errors in FEED will lead to design changes later.

This problem is more common when continuity of FEED contractor to execution is maintained.

But this just raises another question: why aren’t we doing what we know we are supposed to do?
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Why We Short-cut the Front-end

- 33 percent chances of completing front-end engineering

- 32 percent

- 26 percent

All relationships are significant at less than one chance in 1000

All factors are independent contributors
How Do We Measure Team Development?

Team Development Index (TDI)

Project Objectives

- Project objectives:
  - Documented
  - Communicated
  - Agreed to
- Trade-offs clear

Team Composition

- Integrated team
- Key functions represented:
  - Business
  - Ops/Maintenance
  - Engineering
  - Construction
  - Etc.

Roles & Responsibilities

- Team member roles & responsibilities:
  - Defined
  - Agreed to
- Tasks identified
- Risks identified, analyzed, & mitigated

Project Implementation Process

- Project implementation process in place
- Applied consistently on all projects
- Process understood & followed by team
Team Development Drives FEED Completion

Percentage of Projects Completing FEED

Team Development Index

Pr $|\chi^2| < 0.0001$
Owner Operations Involvement Is Critical to Successful Front-End

<table>
<thead>
<tr>
<th></th>
<th>Complete FEED</th>
<th>Limited</th>
<th>Screening Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ops On Team</td>
<td>64%</td>
<td>34%</td>
<td>2%</td>
</tr>
<tr>
<td>Ops Absent</td>
<td>31%</td>
<td>58%</td>
<td>10%</td>
</tr>
</tbody>
</table>
• Framing the issues

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If ya don’t know where you’re goin, you might end up someplace else

Peter Berra, American Philosopher
Lack of clarity and coherence in business objectives is the most important single problem facing industrial projects. Only one project team in three describes the objectives and the tradeoff between objectives as really clear. When objectives and tradeoffs are not clear, teams struggle to complete scope development during the FEL-2 phase ($Pr.|t|<.0001$). Unclear objectives demoralize teams and drive high rates of team turnover ($Pr.|t|<.0001$).
Why Are Clear Objectives So Important?

- Enable the project team to fully engage with the business to find, shape, and develop the right scope
- Shorten FEL cycle and reduce FEL cost
- Reduce the chances of late scope changes by 50 percent
- Make it possible to build a strong and cohesive project team
• Project team needs to know the attributes of a project that will affect business results, such as:
  – Capital and operating costs
  – Cycle time
  – Operating flexibility
  – Product flexibility
  – Aesthetics
  – Community relations
  – Operator labor pool
• They need to know *what the business is trying to accomplish* with the project
• The project team cannot *quantitatively* articulate the cost/schedule trade-off
  – What is the economic value of a month?
  – What gives it so much (or little) value?
  – What exactly will the business have to do to recover if the project is x months late?
• What is the Cost-of-Goods-Sold (COGS) goal? Why?
• What are the vulnerabilities of the business case?
A Real Example of Incoherent Objectives

A large capital-intensive, semi-commodity grassroots project to be executed in China by a US firm

Instructions to the team:

• This plant must be the lowest cost (COGS) for this product in our system
• Low cost will be achieved by maximum use of Chinese Design Institutes and adherence to local standards and codes
• Highest uptime and overall reliability of any plant in the system
• Will use Company’s latest and best (and world’s best) technology
• Environmental performance will follow Responsible Care® as per company policy
• Full protection of Company’s intellectual property is required
## Unclear Objectives Degrade All Key Leading Indicators

<table>
<thead>
<tr>
<th>Projects With:</th>
<th>Clear Objectives</th>
<th>Unclear Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete Teams</td>
<td>68%</td>
<td>35%</td>
</tr>
<tr>
<td>Tasks Assigned</td>
<td>77%</td>
<td>50%</td>
</tr>
<tr>
<td>Team Development Index</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Roles and Responsibilities Defined</td>
<td>78%</td>
<td>37%</td>
</tr>
<tr>
<td>Average Level of Front-end Loading</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Project Controls Index</td>
<td>Good</td>
<td>Fair</td>
</tr>
</tbody>
</table>

*All differences are statistically significant at a Pr>|t|<.0001 or better*
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First Things Have to Be First

- Good construction is the next-to-last link in a value chain that starts much earlier
- Being able to do good construction is the prize that is earned by doing other things well
- Better workface planning and better packaging can incrementally improve construction, but cannot transform productivity unless other things are corrected first
- Owners need to do a better job
  - Clarifying objectives
  - Building the owner teams
  - Completing the front-end
- Then EPC/EPCm contractors need to keep engineering and procurement on schedule
- Only then will construction be amenable to dramatically better performance
Thank you!