Minerals Industry Megaprojects

Presentation for The Chilean Copper Commission Seminar

Chilean Mining Megaprojects: Learning From Experience

June 12, 2014

Edward W. Merrow
A Difficult Point in Mining History

- The past decade has included the best of times and the worst of times
  - The commodities boom of 2003-2008 gave miners a much-needed infusion of profits and capital
  - It also set in motion a process that has cut capital productivity in half relative to just a decade ago

- We now find ourselves caught between prices that are no longer generous and large project costs that threaten to bankrupt the industry

- Our only viable path is to markedly improve our effectiveness, especially in large projects

- The good news is there is a great deal of room for improvement!
Mining Industry Requires Large Projects

• As economic growth resumes in China and India, the demand for copper and other basic minerals will again rise quickly

• Meeting the demand will inevitably require large complex projects

• Large complex projects in every industrial sector, but especially in minerals, are a source of sorrow and loss

• In my talk today I want to discuss why so many large minerals projects fail and suggest that it does not have to be so
Outline

• The Size of the Challenge

• Keys to Success
  – Clear business objectives
  – A strong owner team
  – A complete front-end

• Conclusions
# Database Description

<table>
<thead>
<tr>
<th>Number of Megaprojects</th>
<th>421</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Number of Minerals Megaprojects</em></td>
<td>62</td>
</tr>
<tr>
<td>Average Megaproject Cost <em>(2013 USD)</em></td>
<td>$3.3 billion</td>
</tr>
<tr>
<td><em>Minerals Projects Costs</em> <em>(2013 USD)</em></td>
<td>$2.7 billion</td>
</tr>
<tr>
<td>Number of Mineral Cos. Represented</td>
<td>18</td>
</tr>
<tr>
<td>Average Authorisation Year</td>
<td>2005</td>
</tr>
<tr>
<td>Minerals Megaproject Types</td>
<td></td>
</tr>
<tr>
<td><em>Greenfield developments</em></td>
<td>64%</td>
</tr>
<tr>
<td><em>Expansions</em></td>
<td>15%</td>
</tr>
<tr>
<td><em>New developments at existing sites</em></td>
<td>21%</td>
</tr>
</tbody>
</table>
Geographical Distribution of the Minerals Megaprojects

South America: 34%
North America: 17%
Europe: 4%
Africa: 13%
Middle East: 6%
Australia: 26%
Defining Success and Failure

We deem a project to be a failure if one or more of the following occurred:

- Costs Grew (real) 25% +
- Cost Competitiveness 25% +
- Schedule Slipped 25% +
- Schedule v. Industry Average 50% +
- Severe and Continuing Production Problems (First Two Years) Yes

Success Rate

100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%

- All Megaprojects
- Minerals Megaprojects
Minerals Successes v. Failures
**Striking Difference In Performance**

- **COST INDEX**
  - Minerals Failures
  - Minerals Successes

- **COST GROWTH**
  - 40%
  - 30%
  - 20%
  - 10%
  - 0%

- **PRODUCTION FAILURES**
  - 60%
  - 75%

- **SCHEDULE INDEX**
  - 1.70
  - 1.60
  - 1.50
  - 1.40
  - 1.30

- **SCHEDULE SLIP**
  - 1.00
  - 0.90
  - 0.80
  - 0.70

- **Minerals Successes**
  - Striking Difference In Performance

- **Minerals Failures**
  - Striking Difference In Performance
• Most of the failed minerals projects actually ended up NPV negative even with historically high prices

• Operability problems were more common for minerals than for megaprojects in any other industrial sector

• Operating costs were significantly higher than forecast in >80 percent of minerals projects

• The cost index for minerals failures was double that of non-mineral failures

• The very high cost index indicates that these projects are destroying large amounts of shareholder wealth

• Building in long-term comparative disadvantage
Why So Much Failure?

• Obviously, one of the reasons megaprojects fail so often is simply that they are very difficult

• But why do minerals megaprojects fail more often than other industrial sectors?

• Some argue that minerals projects are more difficult than large projects in other sectors

• But is that really true?
The Usual Minerals Industry Excuses

<table>
<thead>
<tr>
<th>Problem</th>
<th>Minerals v. Other Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>We have more Permitting Problems</td>
<td>Same</td>
</tr>
<tr>
<td>More conflicts with Host Governments</td>
<td>Fewer</td>
</tr>
<tr>
<td>We have to deal with more corruption</td>
<td>Same</td>
</tr>
<tr>
<td>Turnover of Project Leadership</td>
<td>Same</td>
</tr>
<tr>
<td>Local content requirements are worse</td>
<td>Less</td>
</tr>
<tr>
<td>The weather is often severe</td>
<td>Less</td>
</tr>
<tr>
<td>The government controls contracting</td>
<td>Less</td>
</tr>
<tr>
<td>More often in labor-short areas</td>
<td>Same</td>
</tr>
</tbody>
</table>
Real Drivers of Failures are Ordinary

- The business objectives and the priorities amongst objectives were not clear.
- The owner teams were missing at least one critical function during the front-end development in over half the projects.
- The completeness of definition work at sanction (Front-end Loading) was worst of any sector.
- Nearly a third of minerals projects had a major error in the basic (technical) data.
## Minerals Developments Basic Data

<table>
<thead>
<tr>
<th>Basic Data examples* to classify the ore body and the overburden</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lithology and stratigraphy</td>
</tr>
<tr>
<td>• Physical properties and structures</td>
</tr>
<tr>
<td>• Wedge and slab formation and cavities</td>
</tr>
<tr>
<td>• In situ rock temperatures</td>
</tr>
<tr>
<td>• Metals content and metallization process</td>
</tr>
<tr>
<td>• Types of impurities</td>
</tr>
<tr>
<td>• Waste characteristics and volumes</td>
</tr>
<tr>
<td>• Particle sizing characteristics</td>
</tr>
<tr>
<td>• Heterogeneity</td>
</tr>
<tr>
<td>• Size, shape, and attitude</td>
</tr>
<tr>
<td>• Overburden features, properties, angle of repose</td>
</tr>
<tr>
<td>• Topsoil depth</td>
</tr>
<tr>
<td>• Weathered materials</td>
</tr>
<tr>
<td>• Groundwater location, sources, and character</td>
</tr>
</tbody>
</table>

* Includes both physical properties for mine development and metallurgical data for associated processing facilities
Minerals Leads in Basic Data Errors

- The number of Basic (Technical) Data errors in minerals projects is *double* the megaproject average
  - 31 percent v. 15 percent for others
  - Double the average of *petroleum development projects*

- The Basic Data errors drive the poor operability results

- Basic Data errors drive very expensive design changes late in the projects

- Strongly suggest that the minerals industry owners have become far too reliant on contractors to supply technical competence to projects
Real Drivers of Failures are Ordinary

• The business objectives and the priorities amongst objectives were not clear

• The owner teams were missing at least one critical function during the front-end development in over half the projects

• The completeness of definition work at sanction (Front-end Loading) was worst of all industrial sectors

• Nearly a third of minerals projects had a major error in the Basic Data

• All of the above drive a very high rate of late major change in minerals megaprojects
Only the Simplest Minerals Megaprojects were Successful

- Expansions of existing mining operations that required:
  - No new technology
  - No new processing facilities
  - No major infrastructure additions
  - No significant changes to mining conditions
  - No significant amount of revamp/modernization

- In other words, dig it up and put it on a ship bound for China

- That is not a healthy basis for growth!
The Challenges are Large

- Three-quarters of minerals megaprojects have very disappointing outcomes
- The money spent on mineral projects routinely buys much less productive capacity than expected
- That is why the industry return on capital employed (ROCE) is materially poorer than it needs to be
- Almost all of the poor results are the result of self-inflicted wounds
- *And that is very good news indeed!*
• The Size of the Challenge

• **Keys to Success**
  – Clear business objectives
  – A strong owner team
  – A complete front-end

• Conclusions
Megaprojects Are About Value Creation

- If a venture starts with a marginal business case, it will almost always get weaker rather than stronger

- There needs to be enough potential value to satisfy all the other stakeholders and leave enough for the owner to be happy with the result

- It is not the responsibility of the project team to come up with a business case!

- It is the remit of the project team to come up with a scope that best reflects the business objectives
Clear Objectives Are Essential

• Megaproject success requires crystal clear business objectives from all sponsors and especially the lead sponsor

• Clear business objectives are essential to clear project objectives

• Clear project objectives are essential to creating a cohesive project team organisation

• Megaproject objectives are much less likely to be clear than objectives for smaller projects
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
Incoherent Objectives

• Coherent objectives are those that, taken as a set, make sense

• Often project objectives are not coherent, e.g.,
  – Best environmental performance but adherence to weaker local standards
  – Strong intellectual property protection but all local engineering design firms
  – Flexibility with lowest capital cost
  – Highest quality facilities with fastest FEL duration
  – Etc.

• These incoherent objectives make the scoping process unnecessarily difficult

• Discourage the teams and promote failure
Unclear Objectives Negatively Affect All Other Primary Megaproject Drivers

<table>
<thead>
<tr>
<th>Projects With:</th>
<th>Clear Objectives</th>
<th>Unclear Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Teams</td>
<td>68%</td>
<td>35%</td>
</tr>
<tr>
<td>High Owner Involvement</td>
<td>47%</td>
<td>14%</td>
</tr>
<tr>
<td>Adequately Staffed Teams</td>
<td>65%</td>
<td>33%</td>
</tr>
<tr>
<td>Roles and Responsibilities Defined</td>
<td>81%</td>
<td>50%</td>
</tr>
<tr>
<td>Average Level of FEL</td>
<td>Good/Fair</td>
<td>Screening</td>
</tr>
<tr>
<td>Basic Data Problems</td>
<td>10%</td>
<td>46%</td>
</tr>
</tbody>
</table>

All differences are statistically significant at a $Pr>|t|<0.02$ or better
Outline

• The Size of the Challenge

• Keys to Success
  – Clear business objectives
  – A strong owner team
  – A complete front-end

• Conclusions
Owner Teams are Crucial

• In the minerals industry there is a belief that if I hire the right contractor, the project will be fine.

• However, the contractor’s work depends on the accuracy and completeness of the owner’s work to prepare the project.

• The quality of the owner’s work depends heavily on the functional completeness of the team.

• Any missing function translates into changes later.
Integrated Project Teams

**Definition**
Team with *all key functions represented* on a full-time basis

**Requirements**
- Participate *actively* starting in FEL
- Have *decision-making authority* for their function
- *Specific responsibilities* are defined and understood by all team members

**Key to Comparative Advantage***
- Business
- Engineering/Processing
- Environmental
- Cost Estimating
- Scheduling/Planning
- Maintenance
- Operations/Production
- Health & Safety
- Construction
- Project Controls

*Team representation is not limited to these functions and should be determined based on the megaproject complexity. These functions provide the input that makes the project distinctly reflect its primary owner.*
Team Integration Is Important for All
But Crucial for Megaprojects

Effect of Having a Non-Integrated Team on Cost Index

<table>
<thead>
<tr>
<th>Project Size</th>
<th>Cost Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10MM - $25MM</td>
<td>5%</td>
</tr>
<tr>
<td>$25MM - $100MM</td>
<td>10%</td>
</tr>
<tr>
<td>$100MM - $250MM</td>
<td>15%</td>
</tr>
<tr>
<td>$250MM - $500MM</td>
<td>20%</td>
</tr>
<tr>
<td>Megaprojects</td>
<td>30%</td>
</tr>
</tbody>
</table>
### Megaprojects Require Larger Owner Teams

<table>
<thead>
<tr>
<th>Business</th>
<th>Project Controls</th>
<th>Procurement</th>
<th>Finance</th>
<th>Local Government/Authorities</th>
<th>Operations/Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Project Business Sponsor(s)</td>
<td>• Project Controls Manager</td>
<td>• Procurement Coordinator(s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lead Project Financial Modeler</td>
<td>• Lead Cost Engineer</td>
<td>• Supply Chain Manager(s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Supply Chain Lead</td>
<td>• Lead Scheduler/Planner</td>
<td>• Materials Supervisors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>• QA/QC Manager</td>
<td></td>
<td>• Economics and Investment Representatives</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Project Director</td>
<td></td>
<td></td>
<td>• Financial Advisors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Project Managers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lead Interface Manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Information Management Lead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional Services</td>
<td>Project Controls Manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Legal</td>
<td>Construction Managers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Project-savvy Human Resources</td>
<td>• Labour Relations Specialists</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering/Process</td>
<td>Construction Managers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Engineering Manager(s)</td>
<td>• Change Order Specialist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Discipline Lead Engineers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Process Lead(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Principal Geologist*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lead Mine Planner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• R&amp;D Leads (where applicable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment, Health, &amp; Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Environmental Lead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Permitting Lead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Safety Specialist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Health Specialist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Site Security Advisor (where an issue)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Summary
- Megaprojects require larger owner teams involving a wide range of professionals from different departments.
- Each department has specific roles and responsibilities tailored to the project's needs.
- Collaboration and coordination among these teams are crucial for project success.

- **Business** includes project business sponsors, lead project financial modelers, and supply chain leads.
- **Project Management** comprises project directors, project managers, lead interface managers, and information management leads.
- **Professional Services** deals with legal and project-savvy human resources.
- **Engineering/Process** covers engineering managers, discipline lead engineers, process leads, principal geologists, lead mine planners, and R&D leads (where applicable).
- **Project Controls** includes project controls managers, lead cost engineers, lead schedulers/ planners, and QA/QC managers.
- **Construction** involves construction managers and labour relations specialists.
- **Contracts** features contracts managers and change order specialists.
- **Environment, Health, & Safety** includes environmental leads, permitting leads, safety specialists, health specialists, and site security advisors (where an issue).
- **Finance** comprises economics and investment representatives and financial advisors.
- **Procurement** covers procurement coordinators, supply chain managers, and materials supervisors.
- **Local Government/Authorities** handles government/authorities relations managers, government liaisons, and customs specialists.
- **Operations/Maintenance** includes production/operations managers, operations coordinators, and maintenance representatives.
Larger Owner Teams Deliver Better Results

- Increase range of expertise on the team
- Improve ability to be integrated and to be actively involved
- Drive better practices during FEL
- Respond better/faster to crises in execution
  - Proactively identify problems
  - Bolsters contractors when they falter in execution

Each member added to the core owner team increases the probability of having a successful project by more than 3 percent!  \( P > |z| 0.02 \)
Team Integration Is Critical for Megaprojects

Less than 60% of megaprojects teams are integrated during FEL

Biggest effect of non-integration is on production attainment
Internal Cooperation is Essential

• Unlike smaller projects, megaprojects require significant contributions from most of the functions in the corporation

• Including functions that often do not play well with others:
  – Legal
  – Finance
  – Operations
  – Supply chain management
  – Corporate HR
  – Procurement
Team Integration Responsibility

• Should reside with the **business director**
  – Business directors have more authority
  – Operating organisations and most other functions pulled into the project report to the business, not engineering/projects

• Is usually (and incorrectly) assigned to the project director and subproject managers
  – The Project Director defines the requirements
  – The Business Director commandeers the personnel

• If the business is unwilling to provide the required personnel for the project in a timely way, the Project Director should resign
Operations and Maintenance Are Most Frequently Missing Critical Functions

- Typical megaproject may need 3 to as many 20 operations and maintenance people during FEL 2 and FEL 3

- Difficult to achieve because:
  - Operating facilities are short of people
  - Little or no benefit to the loaning organisations
  - Project may not go anywhere anyhow……

- Operations/maintenance input during FEL provides:
  - First-hand knowledge of the facility (or like-facilities)
  - Critical input for engineering definition
  - Input reduces late design changes
  - Specific knowledge around feedstock and operating conditions
  - Maintenance needed to understand layout requirements and maintenance philosophy
Staffing Megaprojects Is Difficult!

• Higher frequency of megaprojects than in the past

• Very few owner organisations are able to adequately staff their large and complex projects
  – Two decades of downsizing owner engineering organisations
  – Aging demographics of the workforce in OECD countries has reduced available personnel and continues to do so
  – Emerging nation personnel often lack experience

• Major international contractors from OECD countries face severe staffing shortages

• The “guard is changing”
Leadership Turnover

• Happens because of:
  – Resignation
  – Retirement
  – Reassignment
  – Promotion
  – Burnout

• Leadership turnover is major disruption to megaproject progress
Continuity of Leadership Is Key

• Teams are temporary organisations with constant member turnover
  – Turnover in leadership positions is extremely damaging
  – Leadership turnover is especially damaging between FEL 2 and project completion

• There is no institutional memory

• Long megaproject durations make continuity difficult to maintain

• Effect of lack of continuity is magnified in megaprojects
Project Director Turnover Degrades All Outcomes

*Data are for all industrial sectors*
• The Size of the Challenge

• **Keys to Success**
  – Clear business objectives
  – A strong owner team
  – *A complete front-end*

• Conclusions
Front-End Loading Generates Success

• The primary problem with minerals megaprojects is that they were poorly prepared at sanction.

• The few projects that were well-prepared succeeded most of the time and generated huge value for shareholders.

• Good preparation at sanction, however, is the culmination of a complex process.
Measuring Front-End Loading

Site Factors

- Labor
  - Availability
  - Cost
  - Productivity
- Local Materials Availability
- Plot Plans and Arrangements
- Soils Data
- Environmental Requirements
- Health and Safety Requirements
- Local Content Requirements

Design Status

- Engineering Tasks
  - Detailed Scopes
  - Feedstock/Product Properties
  - Heat & Mass Balances
  - License Packages
  - Piping & Instrument Diagrams
  - Electric Single-Line Diagrams
  - Major Equipment Specs
  - Take-Off-Based Estimate
- Participation/Buy-In of:
  - Operations
  - Maintenance
  - Business
  - Other Stakeholders

Project Execution Plan

- Design sequenced with Construction Input
- Contracting Plan
- Procurement Plan
- Project Environment:
  - Community Relations
  - Regulatory Liaison
  - Local Content Providers
- Project Organization/Resources
- Team Participants and Roles
- Interface Mgmt & Communication Plan
- Critical-Path Items
  - Identification of Shutdowns for Tie-Ins
  - Overtime Requirements
  - Turnover sequences (near definitive)
- Plans (preliminary)
  - Commissioning & Startup
  - Operation and Maintenance Manpower
  - Quality Assurance
- Resource-Loaded, Integrated, Networked Schedule
- Cost/Schedule Controls
- Ready-to-operate procedures, manuals, training

FEL 3
The IPA Front-End Loading Index

Sanction/FEL 3 Index Rating

End of Pre-Feas/FEL 2 Index Rating

Over-defined for FEL 3

Over-defined for FEL 2
FEL Drives Cost Predictability

Shading represents ±1 standard deviation

Pr > |t| < 0.0001
A poorly front-end loaded megaproject is most likely to be 14 months late to completion!

Shading represents ±1 standard deviation
Failure to produce at or close to the rate promised at authorization is debilitating to the economics of the project!

FEL Reduces Operability Problems

Pr > |X²| < 0.001

Percent of Projects That Were Operability Failures

FEL Index

Inadequate

Poor

Fair

Good

Best
Front-End Loading Still Drives Success

*Data are for Minerals Megaprojects only*
Front-End Loading is More Important for Minerals Megaprojects

- Minerals Megaprojects: $Pr < 0.0001$
- Non-Minerals Megaprojects: $Pr < 0.01$

Cost Overrun vs. Front-End Loading Index

- Best: -$10\%$
- Good: $0\%$
- Fair: $10\%$
- Poor: $20\%$
- Inadequate: $30\%$
- Worst: $40\%$
Team Integration Is a Necessary Condition for Effective FEL

*Missing critical functions during FEL damages quality and completeness of the front-end work*

![Bar chart showing the percentage of projects with and without integrated teams across different FEL index categories.](chart.png)
• The Size of the Challenge

• Keys to Success
  – Clear business objectives
  – A strong owner team
  – A complete front-end

• Conclusions
These Are Not the Good Old Days

- In times past, the minerals industry has depended very heavily on its EPC/EPCm contractors to carry major projects.

- Those days are gone; the major contractors are under enormous stress from retirements.

- They have more megaprojects than they can handle.

- They are struggling with them.

- Owner teams will have to be stronger or failure will become the norm.
The Need is Urgent

- Chile’s special challenges in mining
  - Declining ore grades in copper
  - Relatively small population
  - Declining productivity
  - Water scarcity
  - Lack of oil and gas resources for energy
  - Increasing community concern

- These things make the need for improvement in project planning and execution especially urgent at this time
Finally, A Caution

• Here in Chile, we hear over and over that poor craft labor productivity on projects is the key problem.

• But labor productivity problems are usually *symptoms*, not root causes.

• The root causes are:
  – Unclear or conflicting objectives
  – A functionally incomplete owner team
  – Incomplete front-end development
  – Engineering work that is of low quality and out of sequence
  – Materials and equipment not being on-site when needed

• If these fundamentals are right, projects succeed.

• Strong owners make strong projects!
Thank you for your kind attention!
Minerals Industry Megaprojects

Contact Information

IPA, Inc.
44426 Atwater Drive
Ashburn, VA. 20147 USA
+1 703 729 8300
www.IPAGlobal.com

Ed Merrow
+1 703.726.5300
emerrow@ipaglobal.com