A Dynamic Model for Risk Characterization of Mega-projects and its Impact on Project Financing

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The Mega Project Challenge

Multi-billion dollar industrial projects

- Energy
- Metals
- Petrochemicals
- Transportation

40 TT$ spend in 20 years

X

Negative Returns, Project suspensions and abandonments

Risk of cost & time overruns

Projects need to be **structured, organized, financed** and **managed** in a way, which accommodates change, characterizes risk while minimizing late cost, functionality and schedule impacts.
Understanding Risk based on the Dynamics of Mega Projects is Key

Interactions in mega projects

- Highly inter-coupled
- Feedback driven
- Non-linear nature

Lack of clarity on...

- Understanding of project value
- Assessment of risk premiums
- Structuring the project finance

Ambiguity in the understanding of the dynamics
Current Decision Analysis Methods for Understanding Risk is often Inadequate

- Traditional mechanisms used to establish causal relationships are weak
  ...they ignore feedback effects, multiple interconnections, non-linearities, time delays, and other elements of dynamic complexities

- Various methods to infer causality is constrained
  ....temporal and spatial proximity of cause and effect, temporal precedence of causes, covariation and similarity of cause and effect

- These methods lead to difficulty in large complex projects where
  ....cause and effect are often distant in time and space, actions have multiple effects, the delayed and distant consequences are different than proximate effects

- The assumptions in the traditional models are at aggregate levels
  ....are at higher levels of aggregation, underestimate the tail behavior and non-stationary effects
A Causality Based Approach to Modeling and Characterizing Risks

- Understand cause-effect relationships in terms of
  …attributions, feedbacks, delays and non-linear & higher order effects

- Understand how
  ….projects are structured, elements interact at project, macro and industrial sector level;
  change, shocks and delay effects propagate through the project

- Causality estimation based on facts, data and intuition in the context of
  macro-industry dynamics allows to
  ….understand attributions, feedback effects and time delays in a iterative top-down,
  bottoms-up manner in a “closed loop” system based approach

- Frame dynamic models of project structures and interactions to
  ….infer patterns of behavior based on hybrid simulations using techniques from system
  dynamics and traditional Monte-Carlo mechanisms
### Progression from Static to Dynamic Modeling of Projects, Shapes Project Markets

<table>
<thead>
<tr>
<th>Traditional method of statistical risk modeling</th>
<th>Dynamic risk behavior modeling</th>
<th>Project finance market expansion</th>
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<tbody>
<tr>
<td>Fails to provide meaningful value in risk assessment due to the highly inter-coupled, feedback driven and non-linear nature of interactions in mega-projects.</td>
<td>Associated risks can be characterized, quantified and monitored in a more accurate manner.</td>
<td>Larger institutional investors for funding (e.g. insurance, pension funds).</td>
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<tr>
<td>The unique and craft nature of each project limits the extent of reasonable analysis based on correlations of comparative data.</td>
<td>The transparency and understanding results in meaningful assessment of dynamic risk profiles.</td>
<td>Enhanced market liquidity for project finance.</td>
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<td></td>
<td>Appropriately priced risk premiums.</td>
<td>Greater financial innovation and opportunity expansion in fully functional project finance markets.</td>
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Transformative impact on the industry and society.
...We need a Framework for Structuring, Organizing, Managing and Financing Industrial Megaprojects for dynamic risk understanding
## The Basis for Understanding Complexity in Megaprojects

Large engineering projects are complex because they tend to have:

### Multiple...
- Shaping phases
- Stages of design
- Procurement
- Construction
- Interacting technical disciplines
- Organizations involved (consultants, contractors, vendors,..)
- Possible sequences for accomplishing the work

### Changing...
- Customer requirements
- Performance priorities (schedule, cost, technical)
- Government regulations and standards
- Political Environment
- Work scope
- Technologies
- Resource availability
- Contractor productivity
- Work quality

### Delays...
- Effect of macro-economic shocks
- In discovering rework
- In experiencing full effects of events and conditions that impact the project
- In perceiving true project performance
- In implementing management responses
- In project supply chain behavior
A Two-Stage Framework to Model Large Project Dynamics

Dynamic Behaviour, Risk and Uncertainty Characterization

- Work to be done
- Work being done
- Really done
- Known Rework
- Undiscovered Rework
- Rework discovery
- Obsolescence rate
- Customer changes
- Obsolescence rate
- Customer changes

- Causal Models
- Design Structure Matrix
- Hybrid Simulations
- Project Supply Chains
- Project Databases
- Uncertainty Models
- Flexibility and Options
Project Work-Rework Cycle Model

{Resource, Time}

Work to be done → Work finished

{People, Productivity, Quality}

Work to be done → Work being done → Really done

Known Rework ↔ Undiscovered Rework

Rework discovery

Obsolescence rate

Customer changes
These interacting loops of demand, supply with lags exhibit a stable or unstable dynamic behavior over time.
Stage One Dynamic Model
Stage Two Dynamic Model

Engineering

Construction
Project Outcome Sensitivities to Changes

Engineering Project Sensitivity Model

**Engineering summary**
- Initial Experienced WF: 4.00 empl
- Initial Engineering Deadline: 1,510.00 days
- Productivity of New Engineers: 0.04 tasks/(empl*day)
- Productivity of Experienced Engineers: 0.04 tasks/(empl*day)

**Deadline and Scope**
- Initial Deadline
  - Graph showing timeline from 0 to 2,500 days

**Rework discovery and morale**
- Bar graph showing time to discover rework on work fraction reported done
- Graph showing morale for schedule pressure

**Scope of Work**
- Graph showing scope of work over time

**Resources: Hiring, Productivity, Training, Overtime**
- Initial Experienced Workforce
  - Graph showing empl over time
- Workforce Hiring Lag
  - Graph showing days
- Average Engineer Training Time to be Experience/Learning Curve
  - Graph showing days
- Potential Productivity of Experienced Engineers
  - Graph showing tasks/(empl*day)
- Potential Productivity of New Engineers
  - Graph showing tasks/(empl*day)
- Maximum % Increase in Workforce Hashours
  - Graph showing 0.0 to 1.0
- % Engineering Workforce Ready to do Overtime
  - Graph showing 0.0 to 1.0

**Engineering Workforce**
- Graph showing workforce over time

**Engineering Progress**
- Graph showing progress over time

**Engineering Cost (Million $)**
- Graph showing cost over time

**AcuLead**
## Typical Questions and What If’s the Framework Helps Answer

<table>
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<tr>
<th><strong>Market Risks</strong></th>
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</table>
| **1** | Is there an opportunity for investment in a project in the market? | 1. Potential return envelope  
2. Capacity bounds  
3. Market segments |
| **2** | How would the commodity price evolve? | 1. Price evolution trajectory  
2. Price bounds and sensitivities |
| **3** | How would raw material availability and pricing evolve? | 1. Raw material supply trajectory  
2. Raw material price envelope |
| **4** | Impact of availability and pricing of  
› Land  
› Equipment & technology  
› Labor & workforce | 1. Impact of returns on project  
2. Feasibility of new projects |

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<th><strong>Execution Risks</strong></th>
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| **1** | How should the project be structured? | 1. Complete (EPC) and discrete turnkey option  
2. Number of packages  
3. Difference in cost between contracting options |
| **2** | Impact of  
› Timing and magnitude of Scope changes  
› Delays in decision making  
› Delays in discovering rework/changes | 1. Cost impact  
2. Schedule impact  
3. Workforce impact  
4. Trade-off zone |
| **3** | Impact of supply chain disruptions |  |
| **4** | Impact of unavoidable events  
› Labor strikes  
› Forces majeure  
› Inter-contractor dependencies |  |
Thus Shaping Megaproject Uncertainty through Flexibility Options

Dynamic Risk & Uncertainty

Option to Delay
Option to Expand
Option to Sell Excess
Option to Abandon

Small Plant Alternative
Small Plant + Increased Capacity Alternative
Large Plant Alternative

Expansion option creates value
Abandonment option creates value
Our Project Dynamics Framework and Platforms Expand the Opportunities for Project Finance

- Project Shaping & Analysis
- Project Structuring
- Project Flexibility and Phasing
- Project Risk Modeling
- Project Ratings
- Project Monitoring
- Project Restructuring

Project Finance Innovation

* New Development Bank
** Asian Infrastructure Investment Bank

Investors subscribe

Project Evaluation and Monitoring Board

Company A
Company B
Company N

Project Company

RBI NDB
AIIB
GOI

Share risk

Project bonds (Senior debt)
Subordinated debt
Equity
Enabling the Creation of Competitive Markets for Project Finance

**Megaproject Finance Requirements**
- Long Tenors (20+ years)
- Large Transactions / 500 MM$+
- Large Risk Spreads

**Current Under-Developed Project Finance Markets**
- Market Concentration (Liquid Banks/IFC)
- Low Market Liquidity
- Higher Agency Costs
- Higher Risk Premiums

**Dynamic Risk Understanding & Characterization**

**Stage Gated Risk Quantification**
- Narrowing Risk Spreads
- Megaproject Dynamic Risk-Rating
- Cost-of-Capital Term structure

**Developed Project Finance Markets**
- Large Market Liquidity
- Many Market Players (Pension Funds, FIs...)
- Competitive Cost-of-Capital
- Financial Product Innovation

*AcuLead*
Success in Industrial Megaprojects is all about understanding, characterizing, quantifying and managing risk across the project lifecycle.

Understanding dynamic risk behavior and control points is critical in allocation and control of risks.

Understanding the dynamic behavior of projects during execution is critical in understanding uncertainty, risk and change dynamics.

If risk, uncertainty and change impacts can be characterized it can have transformative effect on Megaprojects, including the markets for project financing.

Our framework for project dynamics is a comprehensive mechanism for understanding complexity, uncertainty and change in Industrial Megaprojects.