

# *Quantitative Risk Analysis for Mining Life Cycle Management.*



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# *Presentation Agenda*

## *(1) Mining Issues and Problems*

- *Mining Activities – Life Cycle*
- *Key Uncertainties*

## *(2) Introduction to Risk Management*

- *Risk Management*
- *Risk Identification and Quantification*

## *(3) Risk Analysis and the Risk Management Process*

- *Quantitative Risk Management Tools*

## *(4) Specific Application Examples*

- *Portfolio Management*
- *Mine Development*

## *(5) Summary*

# *Mining Issues and Problems - Mining Life Cycle Activities*

<i>Life Cycle Activity:</i>	<i>Business Focus</i>
<i>Strategic Planning</i>	<i>Stakeholder Value / Governance Selection of Business / Areas</i>
<i>Portfolio Management</i>	<i>Balance of Portfolio Rationalization of Assets</i>
<i>Prospect Definition</i>	<i>Rationalization of Assets</i>
<i>Development</i>	<i>Project Execution</i>
<i>Start Up / Ramp Up</i>	<i>Production On Stream</i>
<i>Expansion</i>	<i>Project Optimization and Planning</i>
<i>Production</i>	<i>Volumes, Rates, OPEX, Product Slate and Quality</i>
<i>Abandonment</i>	<i>Long Term Liabilities, Closure</i>

# Mining Issues and Problems – Key Uncertainties

<i>Life Cycle Activity:</i>	<i>Business Focus</i>	<i>Key Uncertainties</i>
<i>Strategic Planning</i>	<i>Stakeholder Value / Governance Selection of Business / Areas</i>	<i>Market conditions Political &amp; Social Risk</i>
<i>Portfolio Management</i>	<i>Balance of Portfolio Rationalization of Assets</i>	<i>Market conditions Political &amp; Social Risk Geological Potential</i>
<i>Prospect Definition</i>	<i>Rationalization of Assets</i>	<i>Resource Quality / Quantity Estimate of Potential Value</i>
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<i>Expansion</i>	<i>Project Optimization and Planning</i>	<i>Capital Cost, Schedule Technology, Interference</i>
<i>Production</i>	<i>Volumes, Rates, OPEX, Product Slate and Quality</i>	<i>Ore grade, Plant operability, Operating team performance, Regulatory Issues</i>
<i>Abandonment</i>	<i>Long Term Liabilities, Closure</i>	<i>Cumulative Impact of Operating Decisions, Environmental and Social Issues</i>

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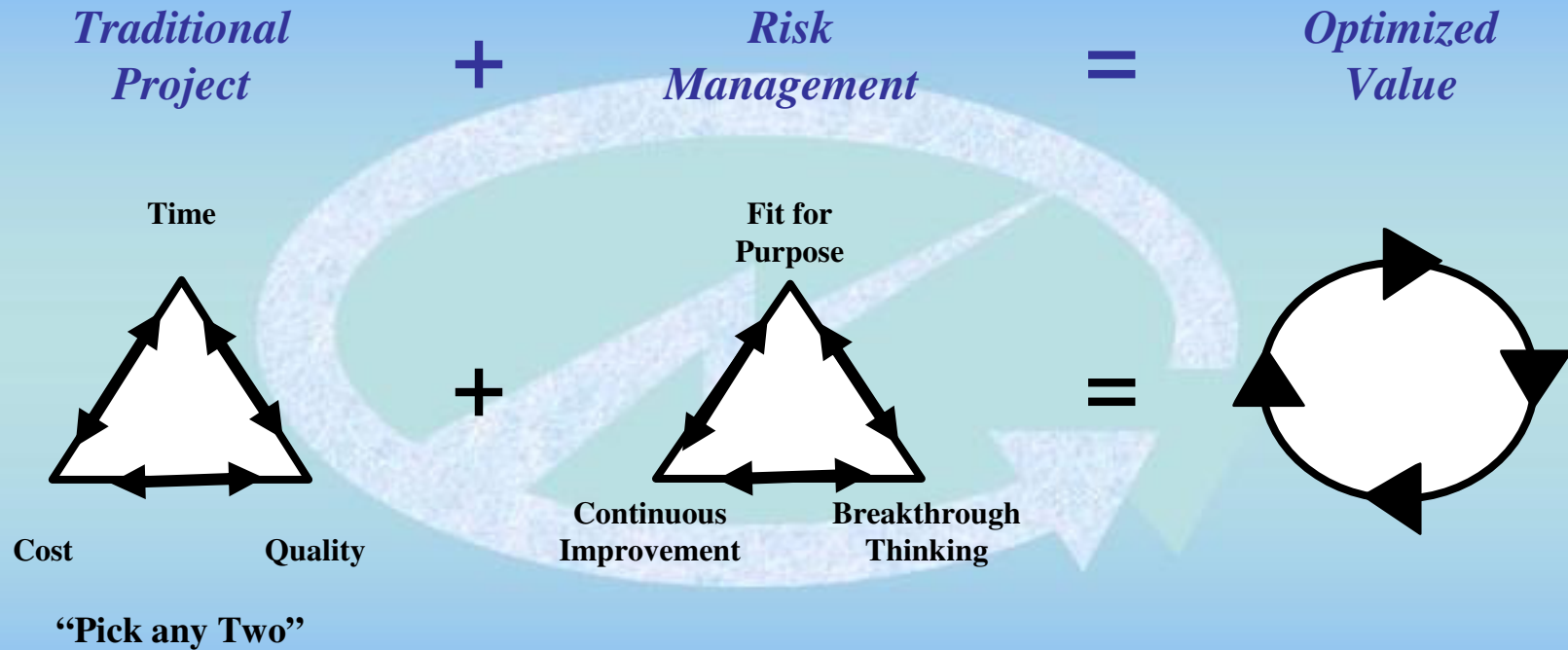
- *Quantitative Risk Management Tools*

## *(4) Specific Application Examples*

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# Project Management Mantras



*Risk Management is used to maximize the Project value by testing strategies to find the optimum.*

# *Three Techniques are available that address different levels of Risk Management*

## *Qualitative*

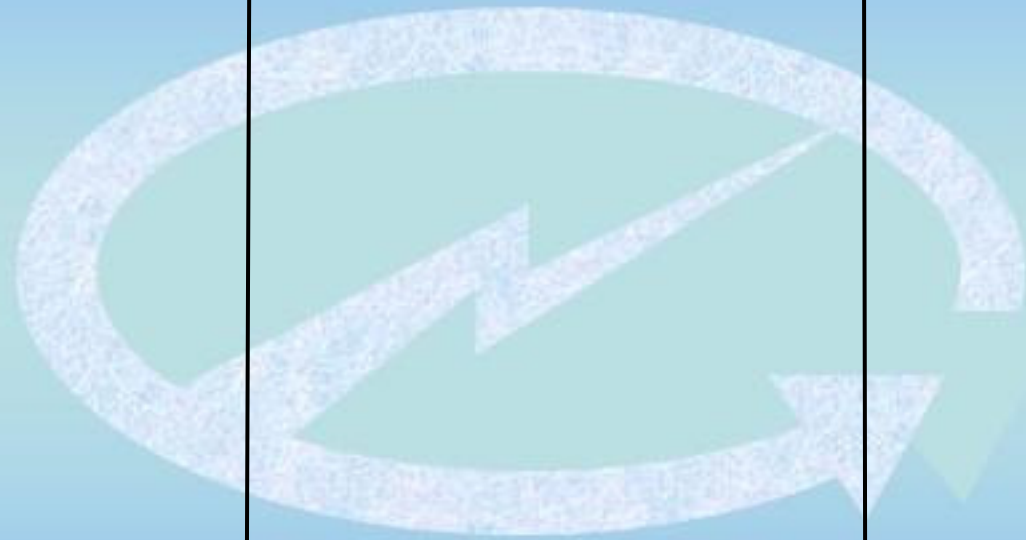
*Identify key project risks*

## *Range Estimating*

*Calculate Appropriate Contingency Targets*

## *Quantitative Analysis*

*Optimize project configuration and shareholder value.*



# *Objective*

# Three Techniques are available that address different levels of Risk Management

<i>Qualitative</i>	<i>Range Estimating</i>	<i>Quantitative Analysis</i>
<i>Identify key project risks</i>	<i>Calculate Appropriate Contingency Targets</i>	<i>Optimize project configuration and shareholder value.</i>
<i>Large Group – Consensus Based</i>	<i>Small group Consensus based or individual interviews (Template driven).</i>	<i>Broad Expert Group with judgment based assessment.</i>

## Assessment



# Three Techniques are available that address different levels of Risk Management

<i>Qualitative</i>	<i>Range Estimating</i>	<i>Quantitative Analysis</i>
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<i>Considers the fixed execution plan, assumptions and some external risks.</i>	<i>Considers the project execution plan and assumptions.</i>	<i>Considers all strategic options, execution plans and external risks.</i>

*Scope*

# Three Techniques are available that address different levels of Risk Management

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<i>No Modeling</i>	<i>Tool-Driven Modeling focusing on one aspect of project (Cost, Schedule or Economics).</i>	<i>Custom Integrated modeling highlighting cross impacts from project areas.</i>

## Modeling

# *Three Techniques are available that address different levels of Risk Management*

<i>Qualitative</i>	<i>Range Estimating</i>	<i>Quantitative Analysis</i>
<p><i>Identify key project risks</i></p> <p><i>Large Group – Consensus Based</i></p> <p><i>Considers the fixed execution plan, assumptions and some external risks.</i></p> <p><i>No Modeling</i></p> <p><i>No Correlation</i></p>	<p><i>Calculate Appropriate Contingency Targets</i></p> <p><i>Small group Consensus based or individual interviews (Template driven).</i></p> <p><i>Considers the project execution plan and assumptions.</i></p> <p><i>Tool-Driven Modeling focusing on one aspect of project (Cost, Schedule or Economics).</i></p> <p><i>Tool-Driven based on distribution, determined by risk analyst</i></p>	<p><i>Optimize project configuration and shareholder value.</i></p> <p><i>Broad Expert Group with judgment based assessment.</i></p> <p><i>Considers all strategic options, execution plans and external risks.</i></p> <p><i>Custom Integrated modeling highlighting cross impacts from project areas.</i></p> <p><i>Conditioning Variables to capture underlying risks &amp; correlation, determined by project team.</i></p>

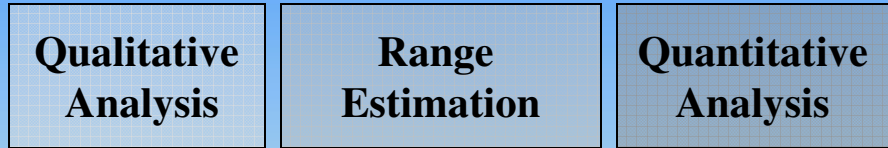
## *Correlation*

# *Three Techniques are available that address different levels of Risk Management*

<i>Qualitative</i>	<i>Range Estimating</i>	<i>Quantitative Analysis</i>
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<i>No Correlation</i>	<i>Tool-Driven based on distribution, determined by risk analyst</i>	<i>Conditioning Variables to capture underlying risks &amp; correlation, determined by project team.</i>
<i>Project Team, Constructors, and EPCM Contractors.</i>	<i>Project Team, Constructors, and EPCM Contractors</i>	<i>Project Team, Owners, Stakeholders, Constructors &amp; EPCM Contractors.</i>

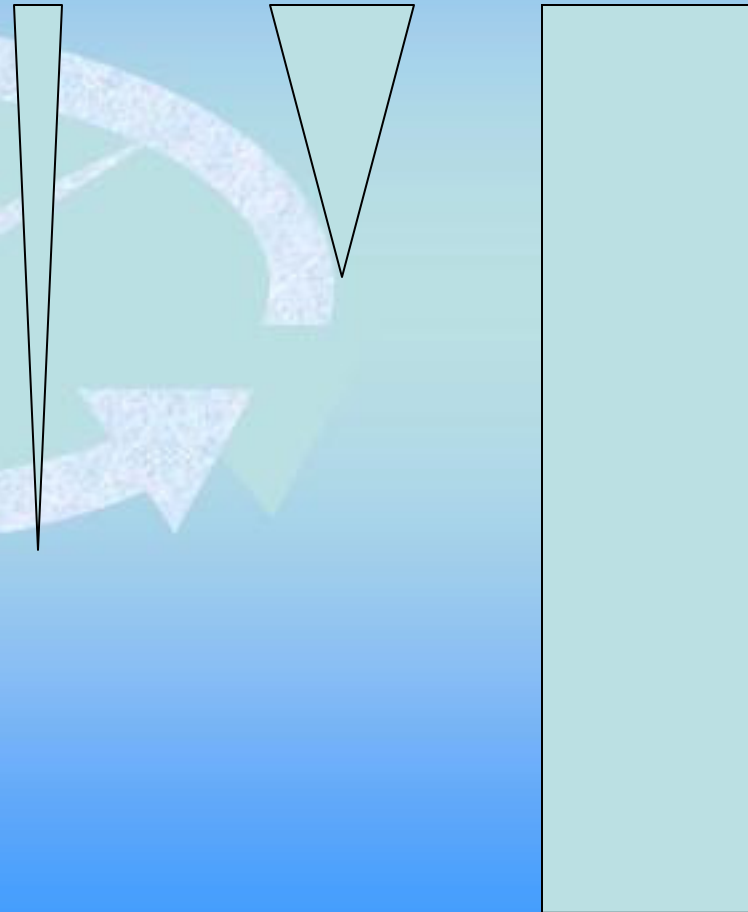
## *Audience*

*Properly conducted risk analysis builds on the early tools used for qualitative analysis (KT, SWOT) and range estimation to include all the risk and opportunity impacts on a project or decision.*



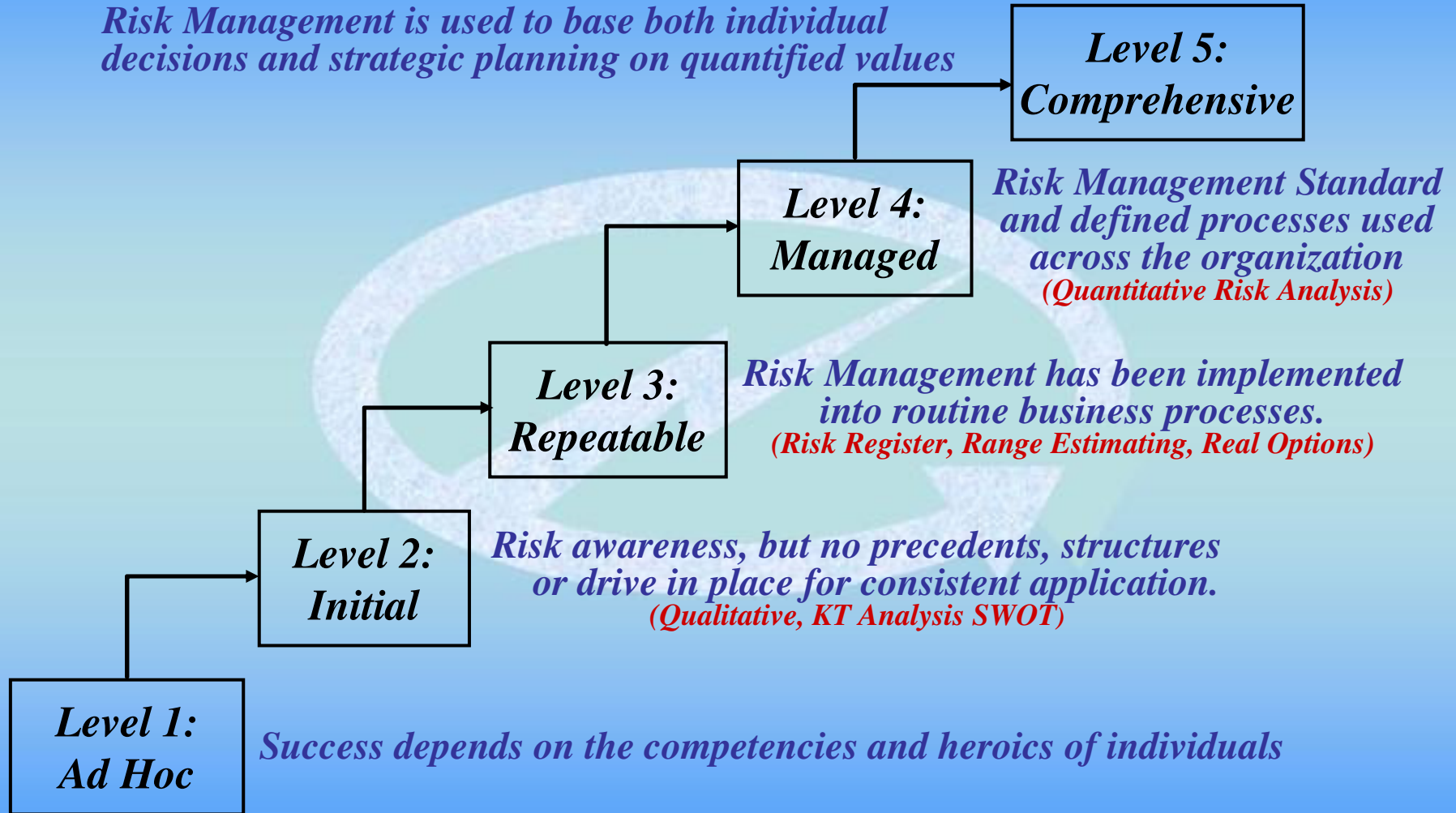
Comprehensive Risk Envelope for decision making

- Outcome Uncertainty**  
(Cost, Schedule or Economic)
- Risk Variable Correlations**
- Integrated Modeling**  
(Cost & Schedule)
- External / Event Driven Risk Impacts**
- Outside the Box Risks**  
(Project Assumptions)
- Strategic and Tactical Alternatives Review**
- Full Cycle Analysis**  
(Production / Revenue / Finance / Returns)
- Underlying Risk Drivers**  
(Corporate / Economic / Regulatory / Political Environment)



# Five Levels of Risk Management Maturity\*

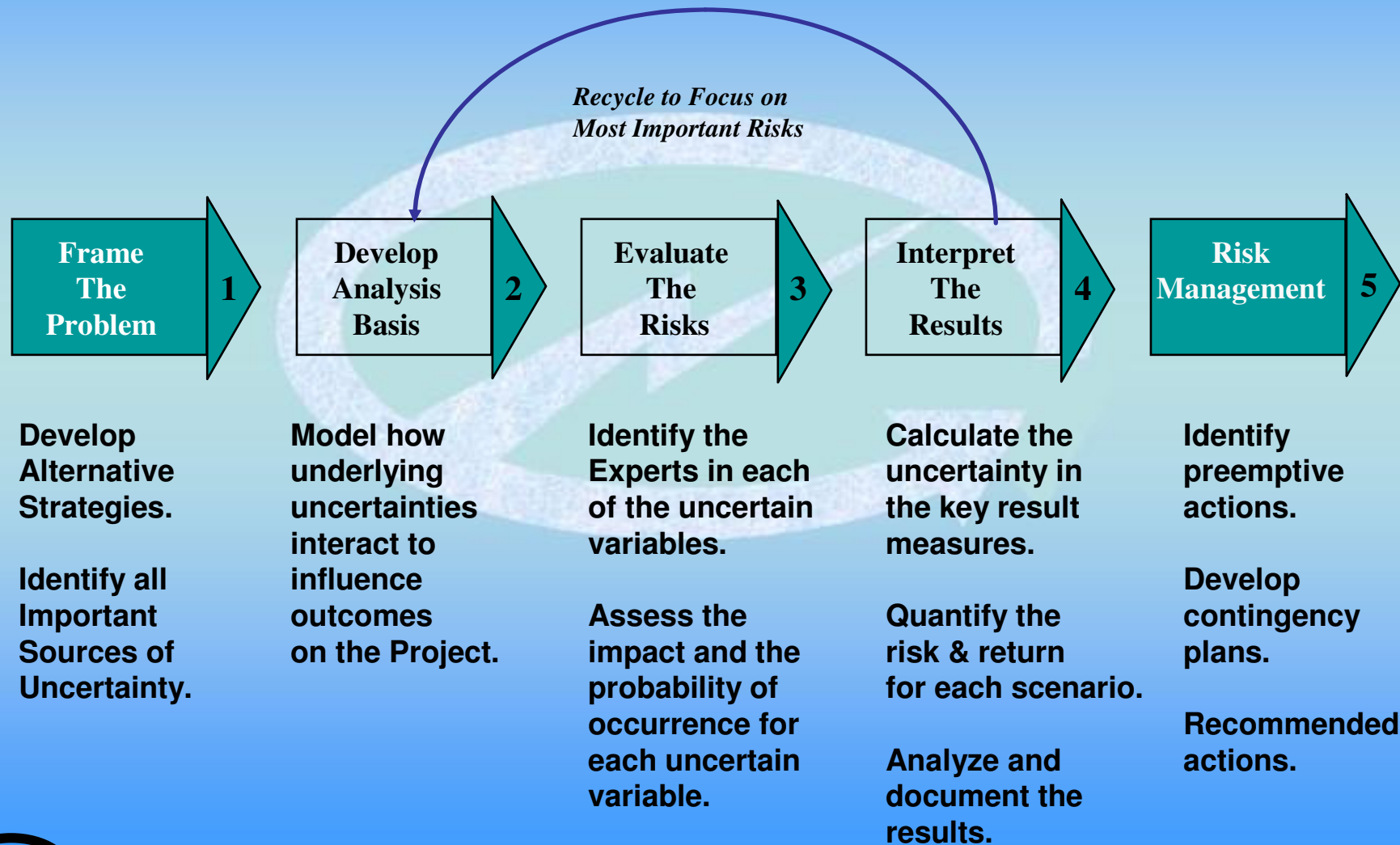
*Risk Management is used to base both individual decisions and strategic planning on quantified values*



## *Quantitative Risk Analysis is a rigorous and comprehensive process that:*

- *Frames the decision problem and documents a consistent set of assumptions, limitations and constraints ...*
- *Allows all strategies to be tested in an uncertain environment and compared in a quantified manner...*
- *Identifies all sources of uncertainty and assesses the probability of occurrence and impact on the results ...*
- *Provides an effective communication tool so that the assumptions and uncertainties are clearly communicated to stakeholders...*
- *Uses conditioning variables to model the underlying uncertainties to ensure the project/activity performs in a logical manner...*
- *Assists in mitigation planning, implementation tactics, and identifies opportunities to enhance project/activity value.*

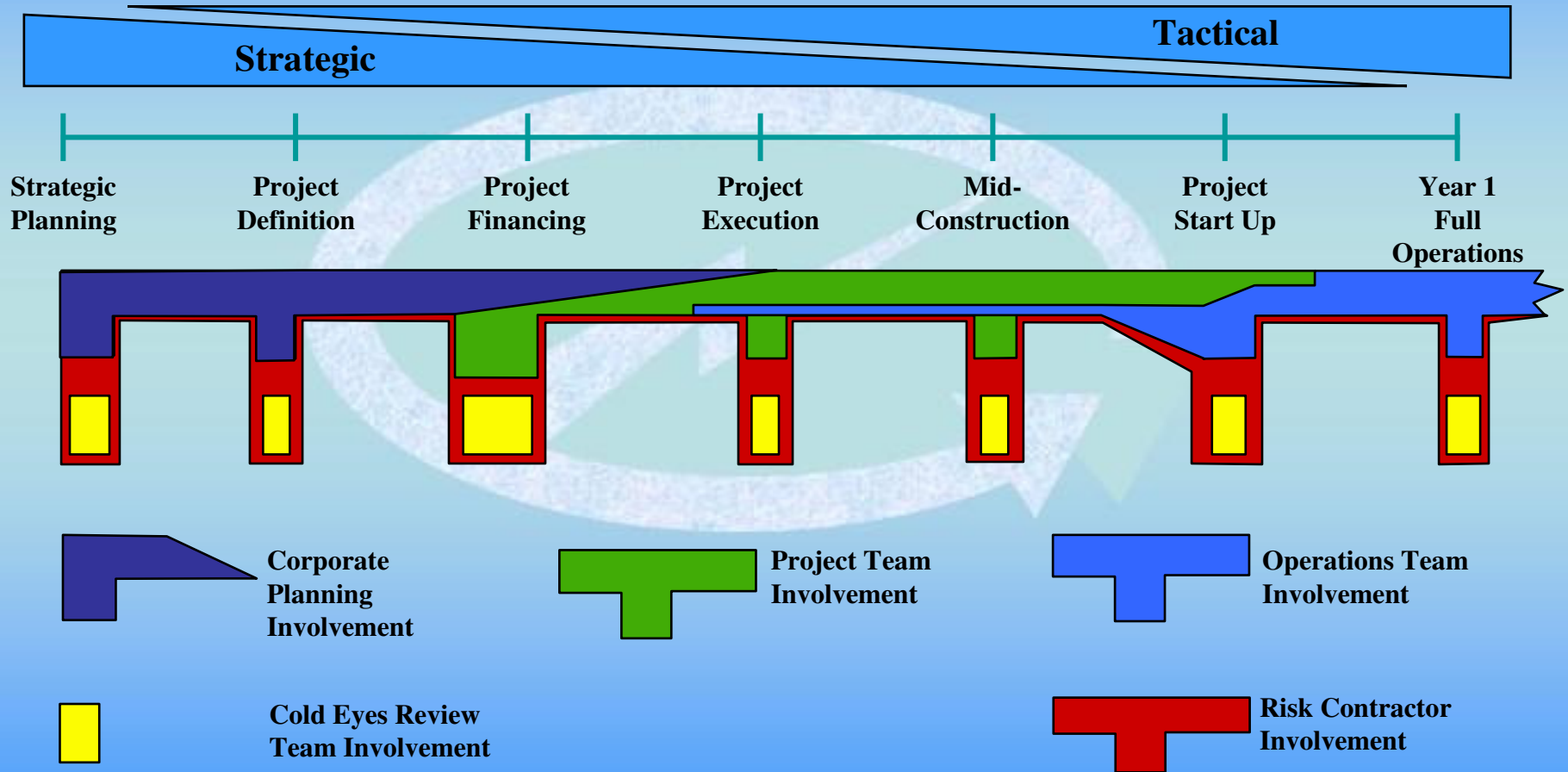
# *A rigorous process is applied consistently to evaluate all projects*





# Risk Management Process

*An effective Risk Management plan must re-evaluate the risks on the project and their impacts throughout the project life cycle. Each phase of the risk analysis involves a different focus and a different mix of disciplines.*



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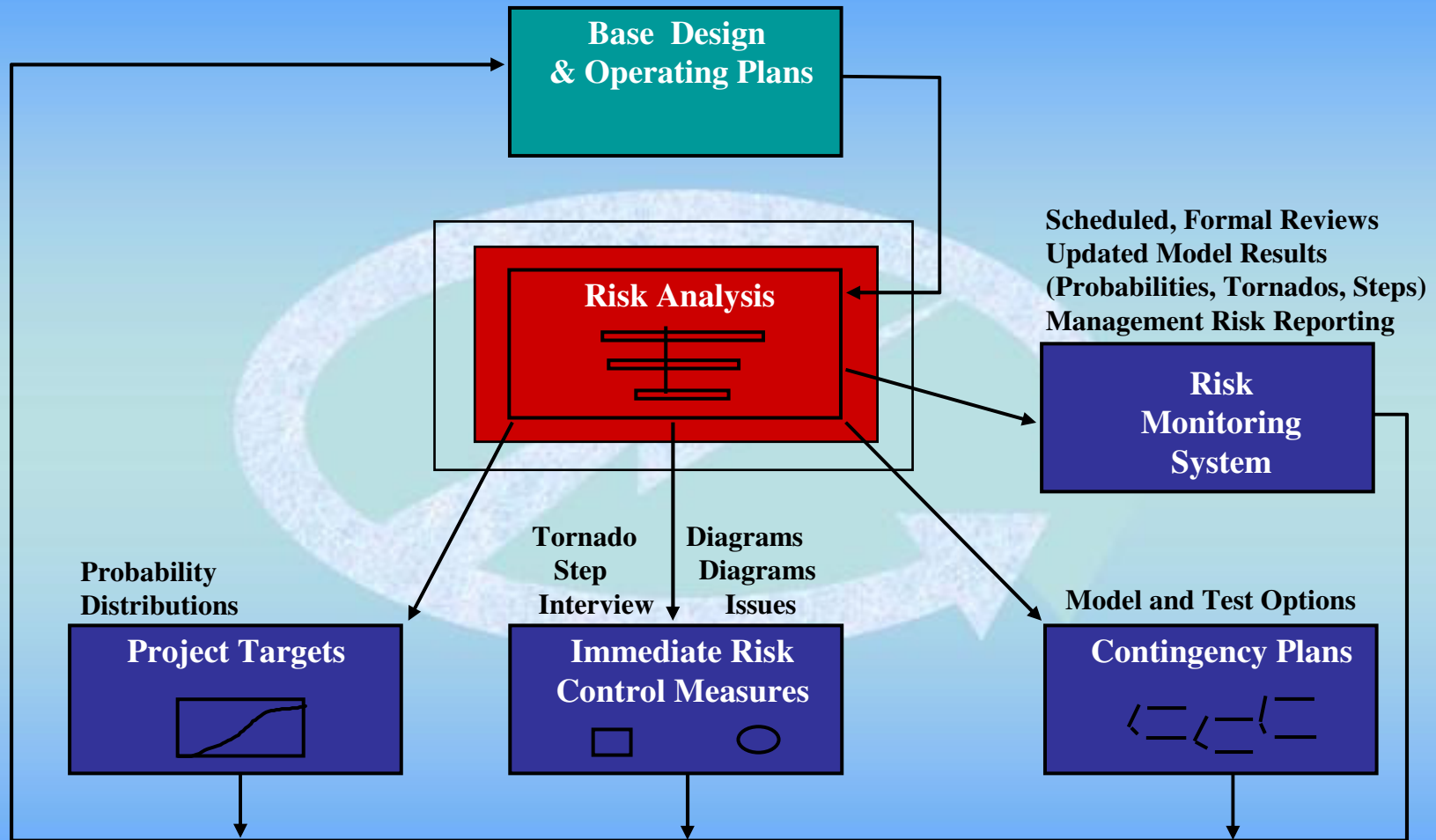
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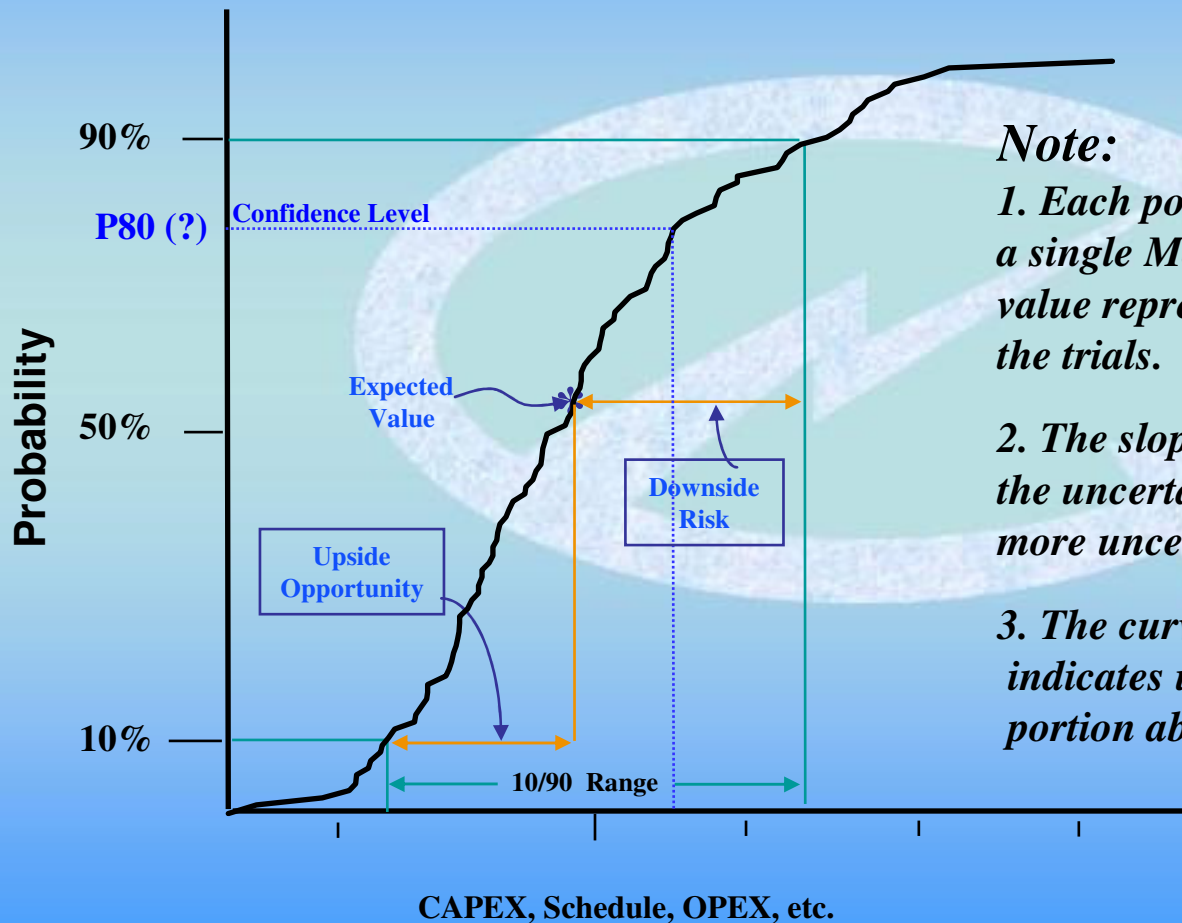
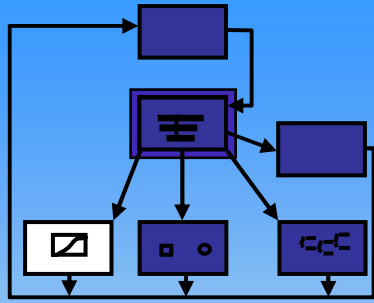
# *Risk Analysis is the centerpiece of a Risk Management Process*



*There are four key outputs from a comprehensive Risk Analysis*

# Project Targets

*The probability distribution illustrates the full range of project uncertainty and is used to set the project targets at appropriate confidence levels.*

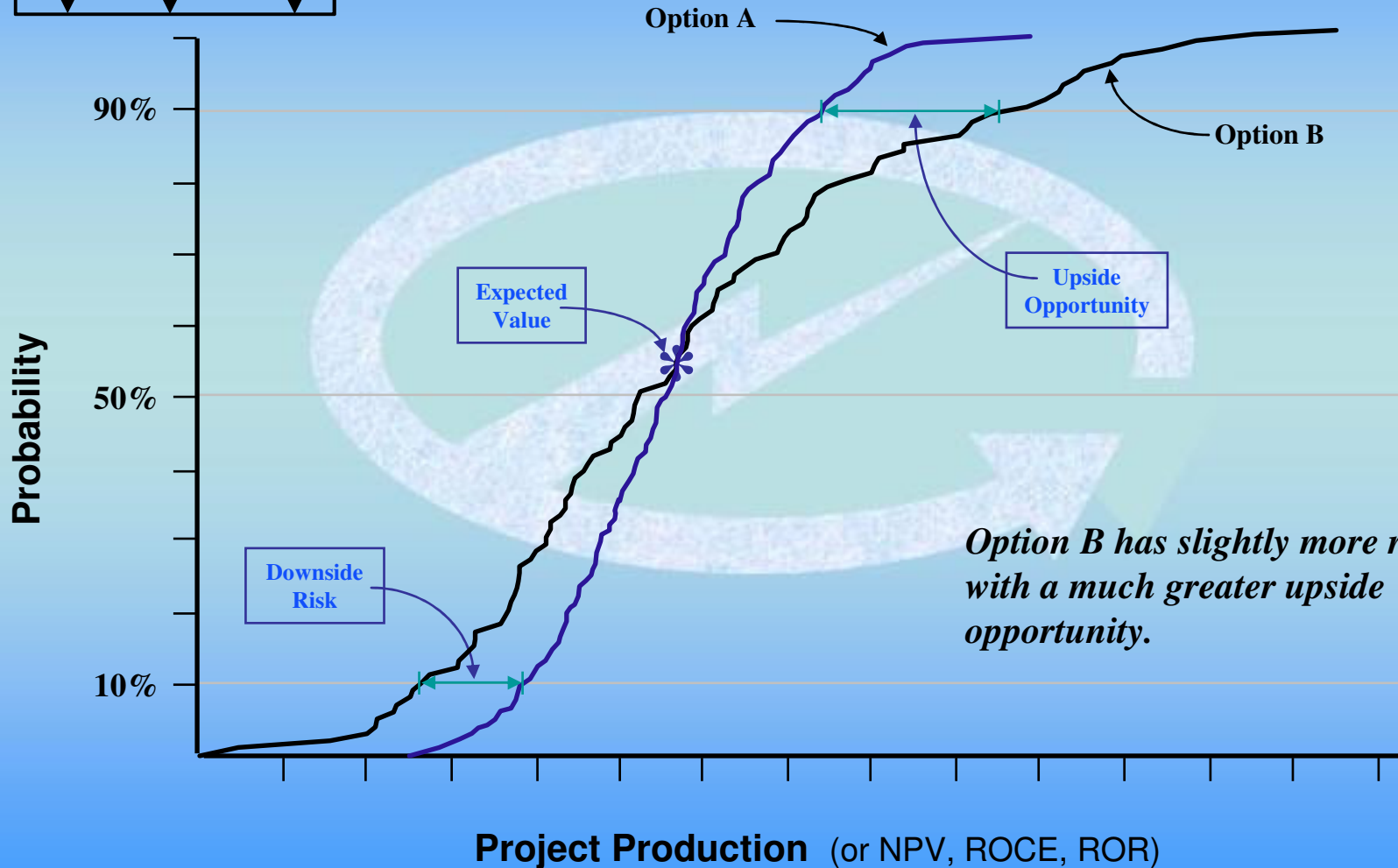
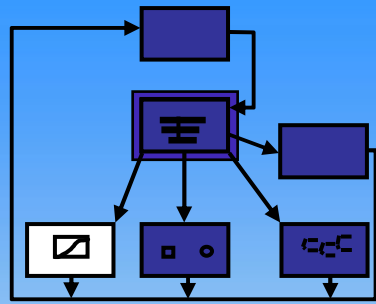


## **Note:**

- 1. Each point on the curve is a result from a single Monte Carlo trial. The expected value represents the average value of all the trials.*
- 2. The slope of the 10/90 range represents the uncertainty, the flatter the curve, the more uncertainty.*
- 3. The curve below the expected value indicates upside opportunity, the portion above shows the downside risk.*

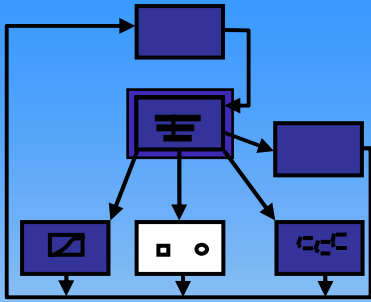
# Project Targets

Probability distributions illustrate opportunity and risk trade-offs, and can be used to select the best project option.



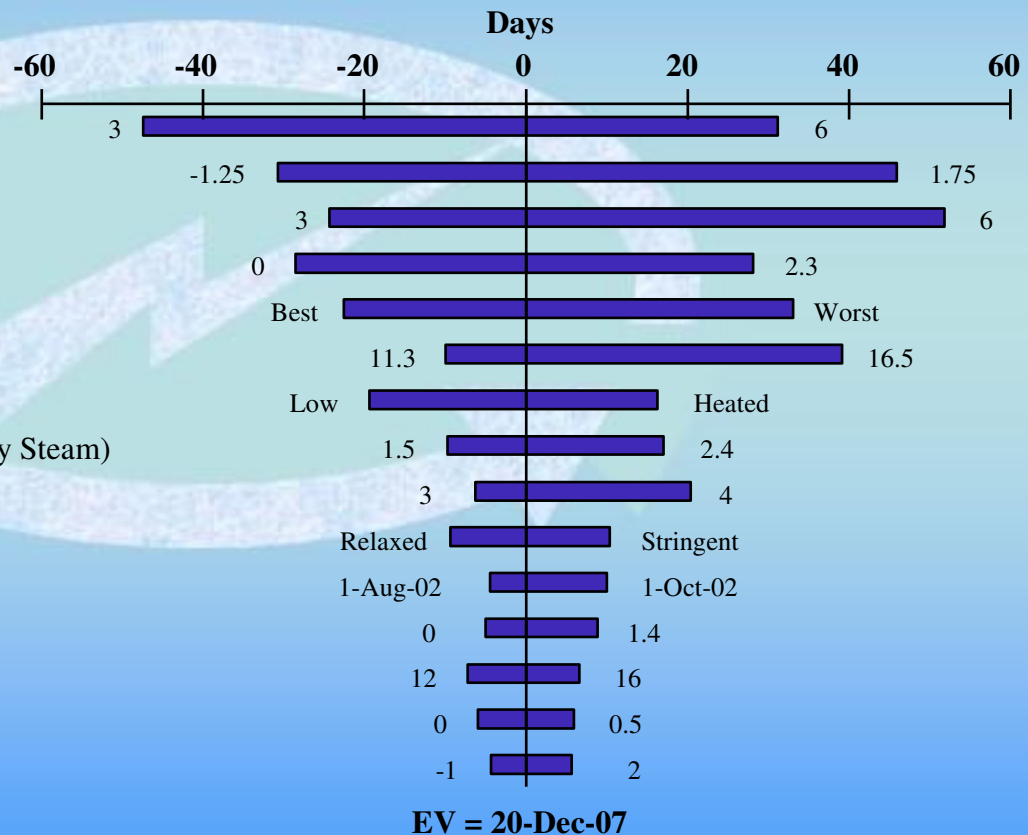
# Immediate Risk Control Measures

The tornado diagram identifies and ranks the key project risks and is a tool that helps the project team to focus on the most important drivers.



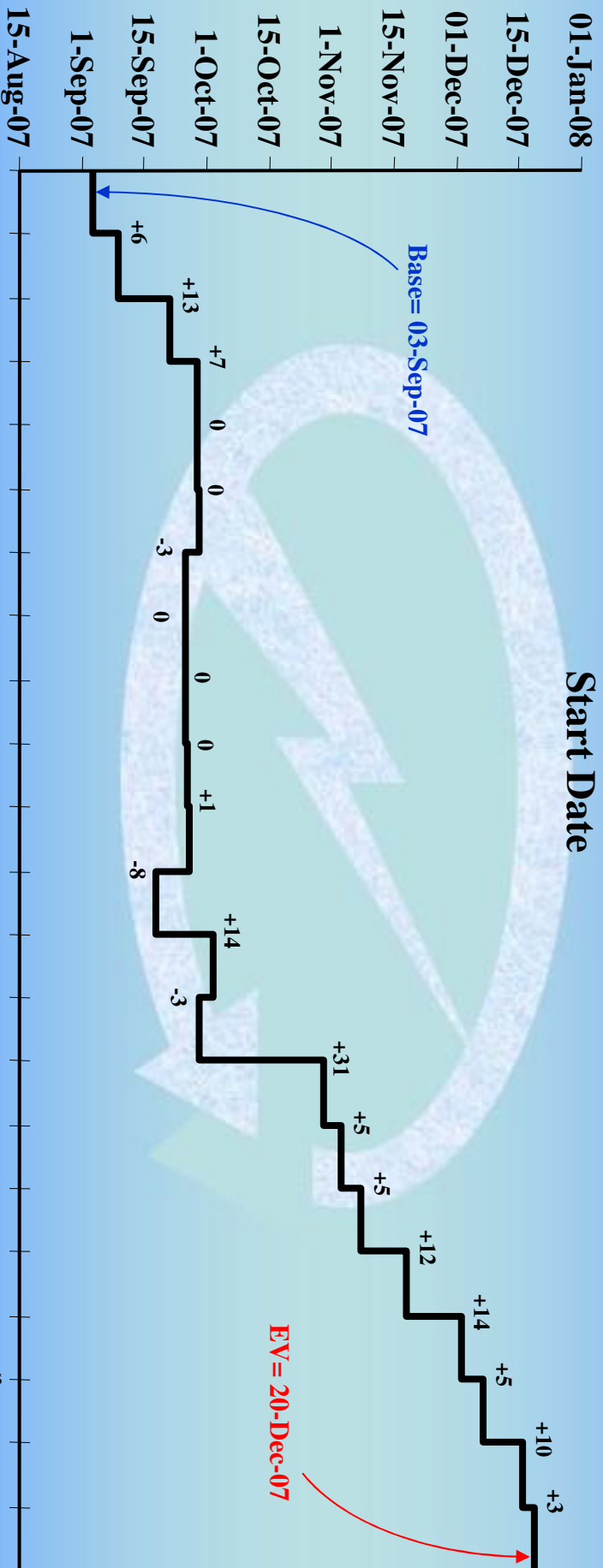
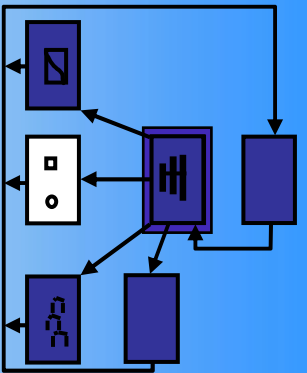
## Start Date

- Road Preparation Duration
- Labour Productivity Delays
- Plant Pad Preparation Duration
- Labour Unrest Delays
- Execution Organization Performance
- Regulatory Duration
- Competing Project Environment
- Start-up & Commissioning Duration (Early Steam)
- Terms of Reference - Duration
- Regulatory Environment
- Terms of Reference - Application Date
- Labour Availability Delays
- OTSG Manufacture & Delivery Duration
- Weather Delays
- Long Lead Equipment Delays



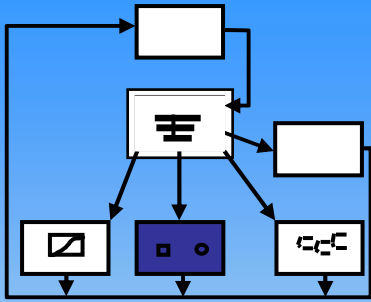
# Immediate Risk Control Measures

The Step Diagram demonstrates where the growth from the base estimate to the Expected Value occurs, and identifies key factors impacting the cost.



# Immediate Risk Control Measures

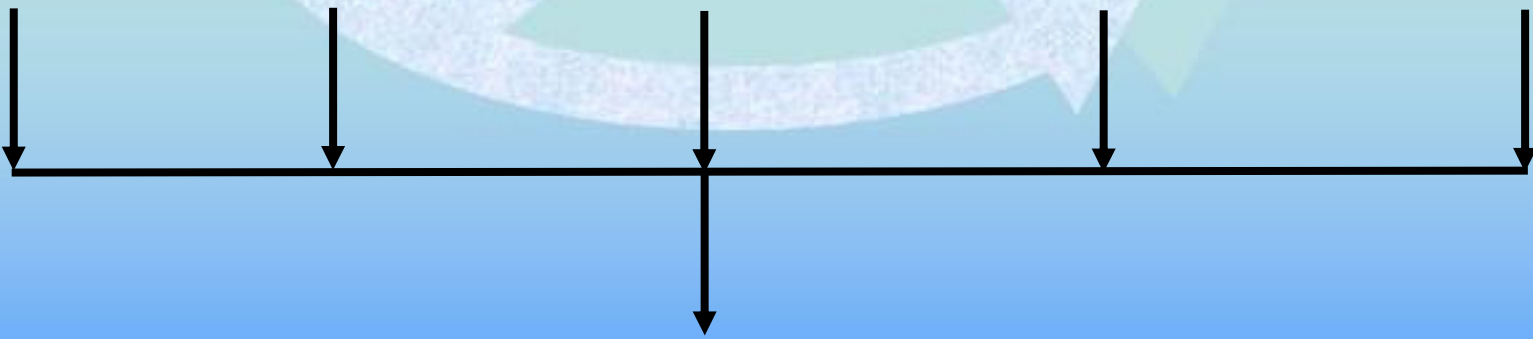
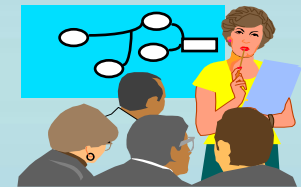
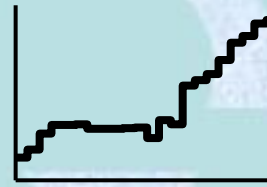
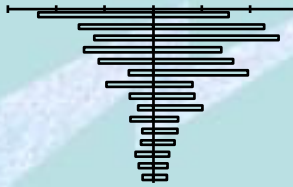
*A complete risk register considers all sources of information available for the project uncertainties.*



Project Documentation

Qualitative Analysis

Quantitative Analysis

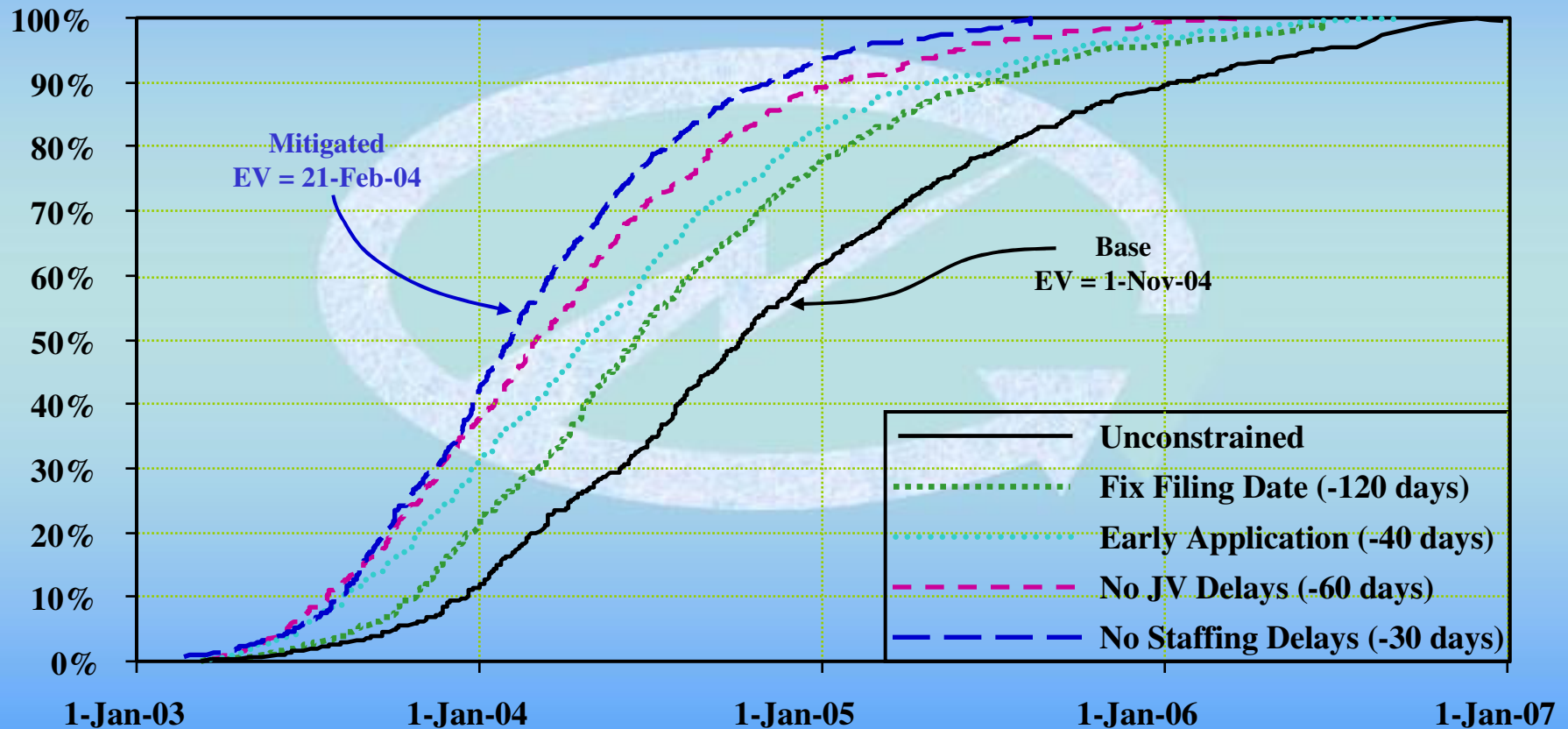
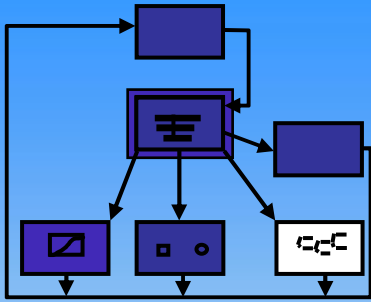


Risk Register



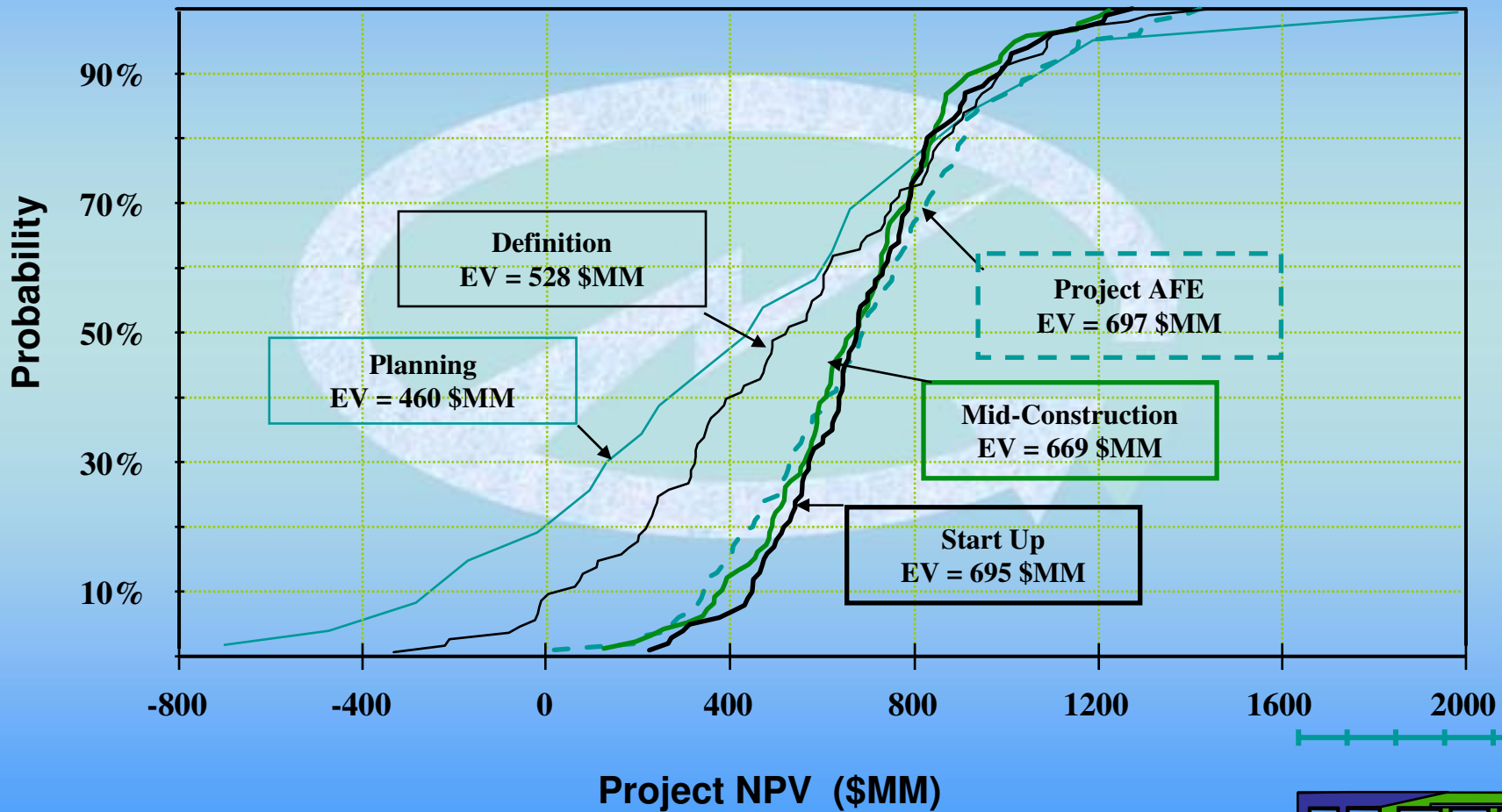
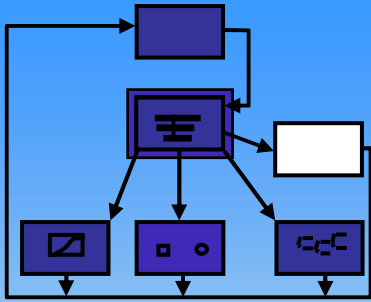
# Contingency Plans

*The analysis can be used to evaluate impacts of schedule risks, and test mitigation steps to show the potential for schedule advancement. Incremental mitigation can be applied to reach an acceptable target date.*



# Risk Monitoring System

Use of risk analysis throughout the project life helps the project team to focus on the most important risks for each stage of development, resulting in a better defined project (i.e. less risk).



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# Mining Issues and Problems – Key Uncertainties

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# Mining Issues and Problems

*Early in the Project life cycle the analysis should be focused at a high level to level to ensure that the right strategic decision is taken.*

<i>Activity:</i>	<i>Business Focus</i>	<i>Key Uncertainties</i>
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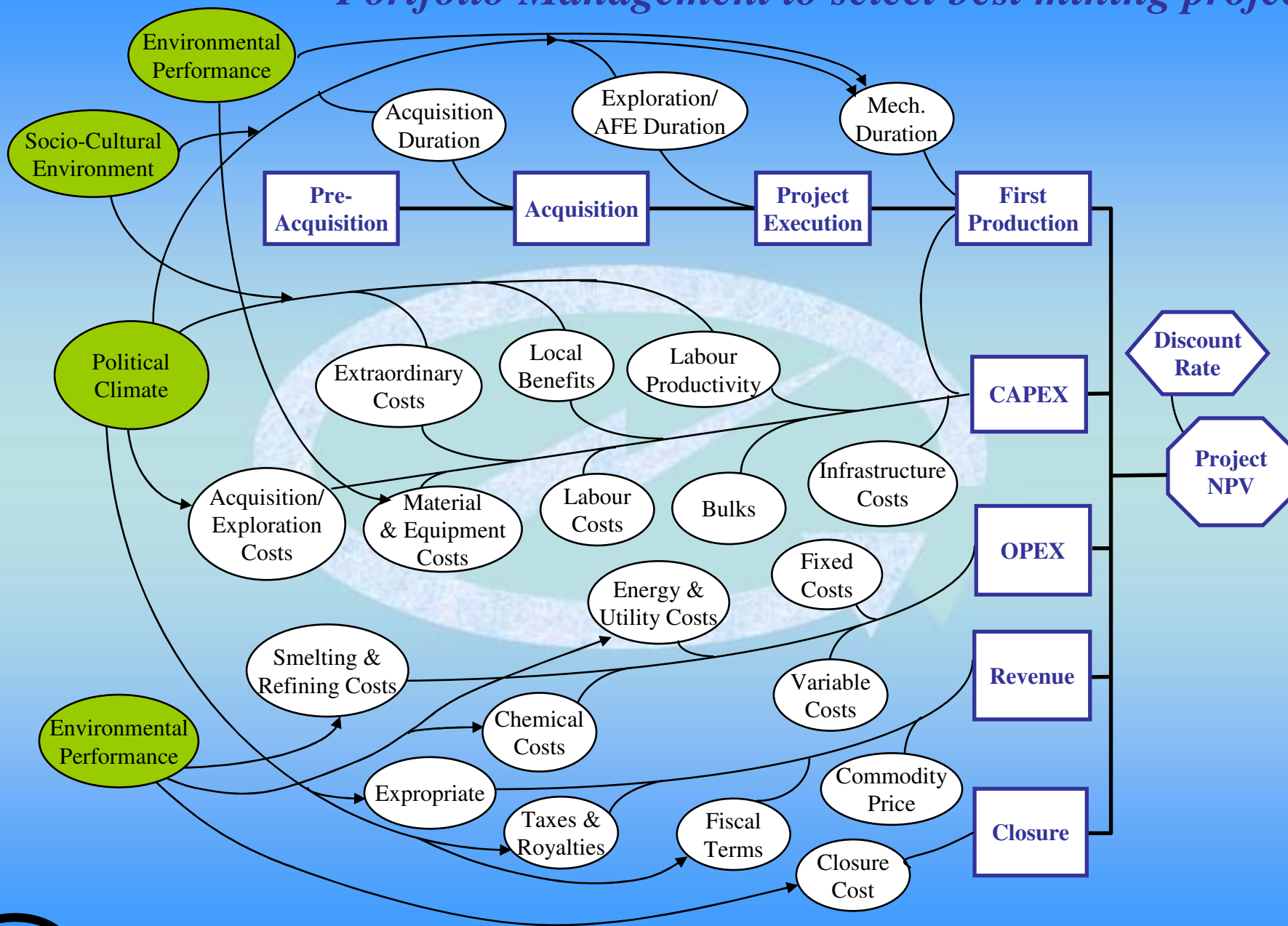
## *Strategy Table for Country Risk Analysis*

<b>Decisions</b>						
<i>Strategy</i>	<i>Country</i>	<i>Commodities</i>	<i>Mining Extraction</i>	<i>Processing</i>	<i>Smelting &amp; Refining</i>	<i>Markets</i>
<i>Increasing Reserves</i>	<i>Canada</i>	<i>Polymetallic</i>	<i>Open Pit</i>	<i>Heap Leach</i>	<i>In Country: onsite</i>	<i>In Country</i>
<i>Competitive Need</i>	<i>Indonesia</i>	<i>Precious Metals</i>	<i>Underground</i>	<i>Standard Flotation &amp; Concentration</i>	<i>In Country: offsite</i>	<i>Regional</i>
<i>Competitive Advantage</i>	<i>Russia</i>	<i>Industrial Minerals</i>	<i>InSitu Leach</i>	<i>Solvex</i>	<i>Out Of Country</i>	<i>International</i>

*Selected Strategy*

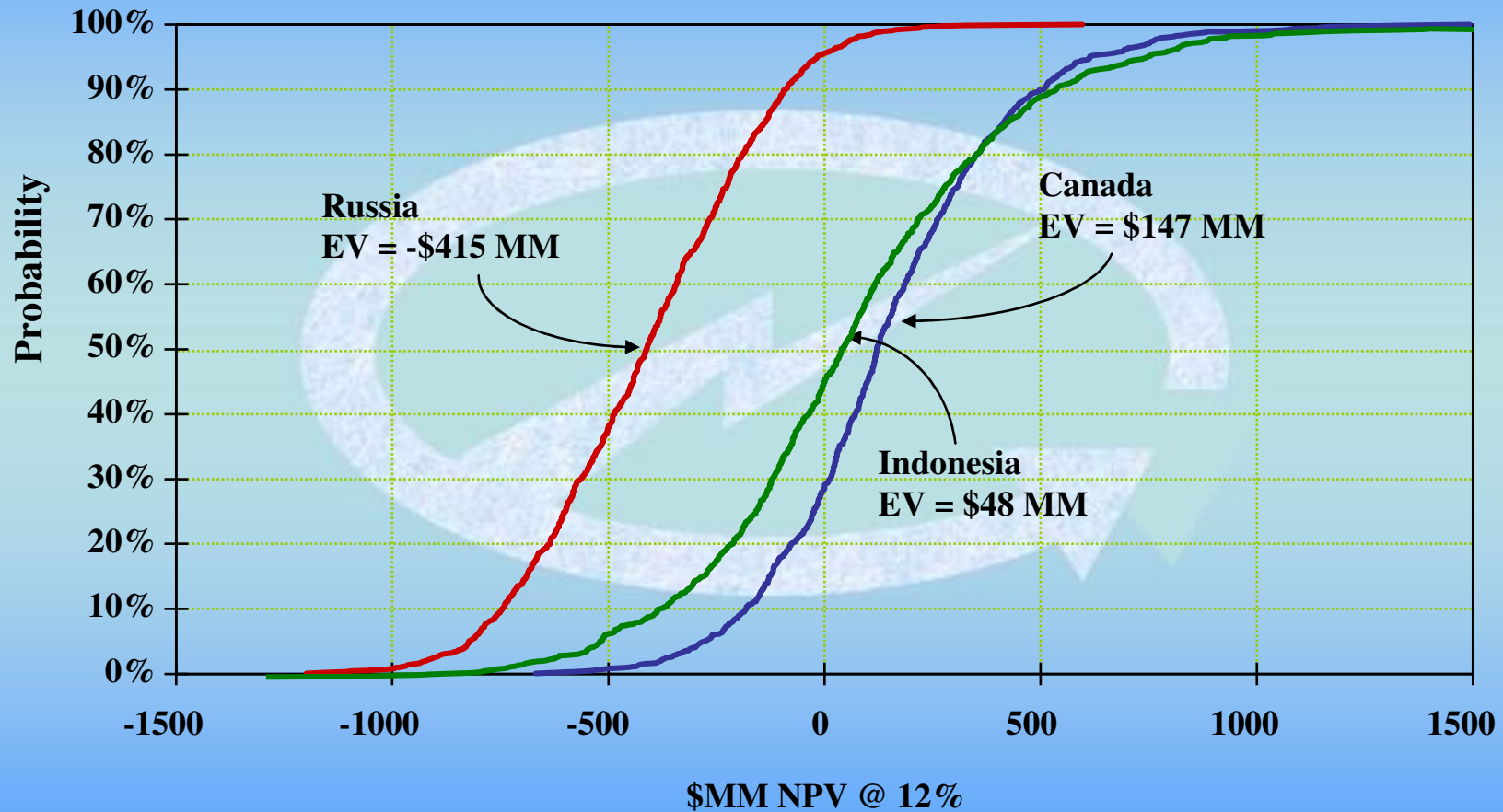
*Options*

# Portfolio Management to select best mining project



# Portfolio Management

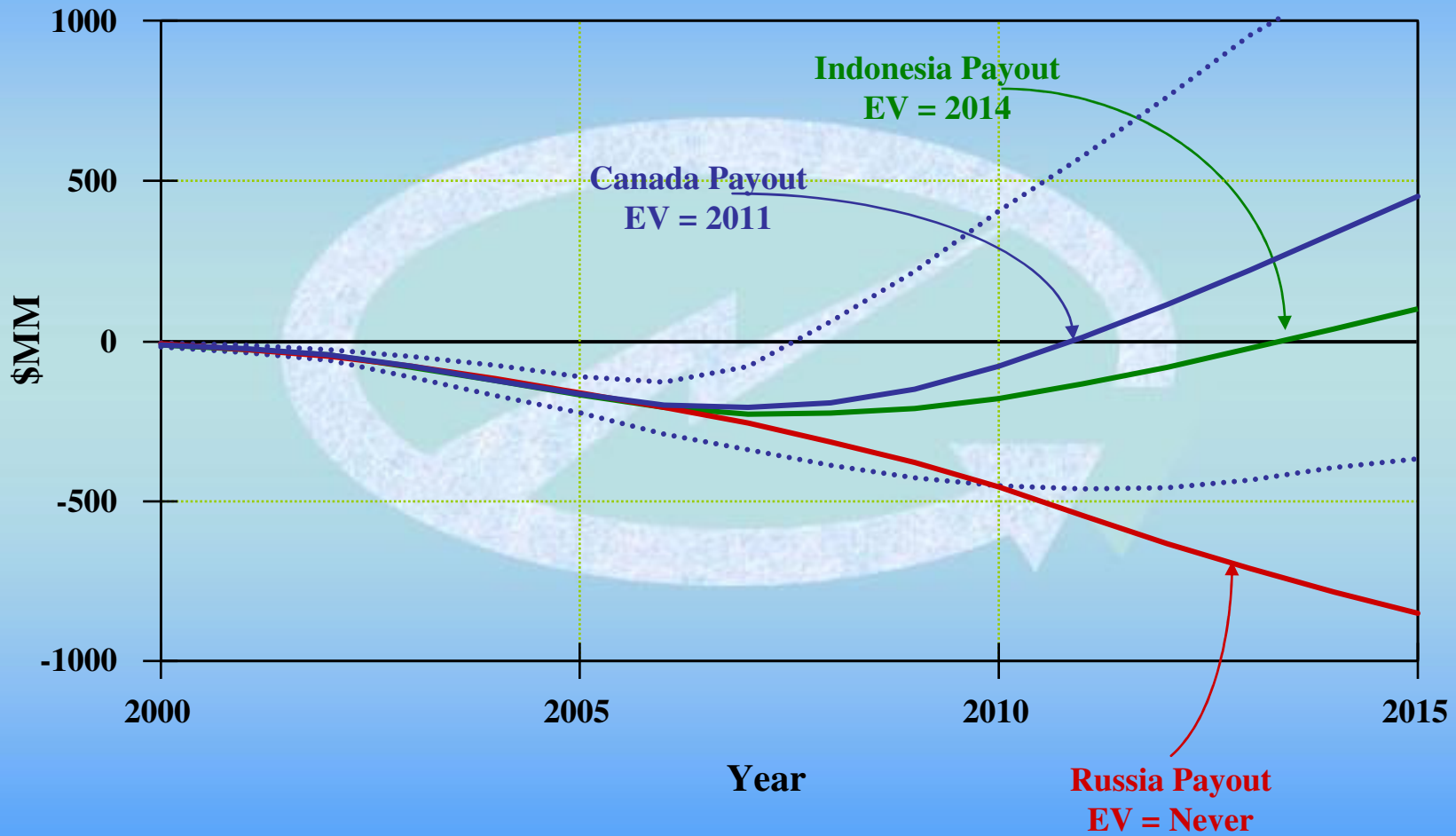
## NPV Country Case Comparison





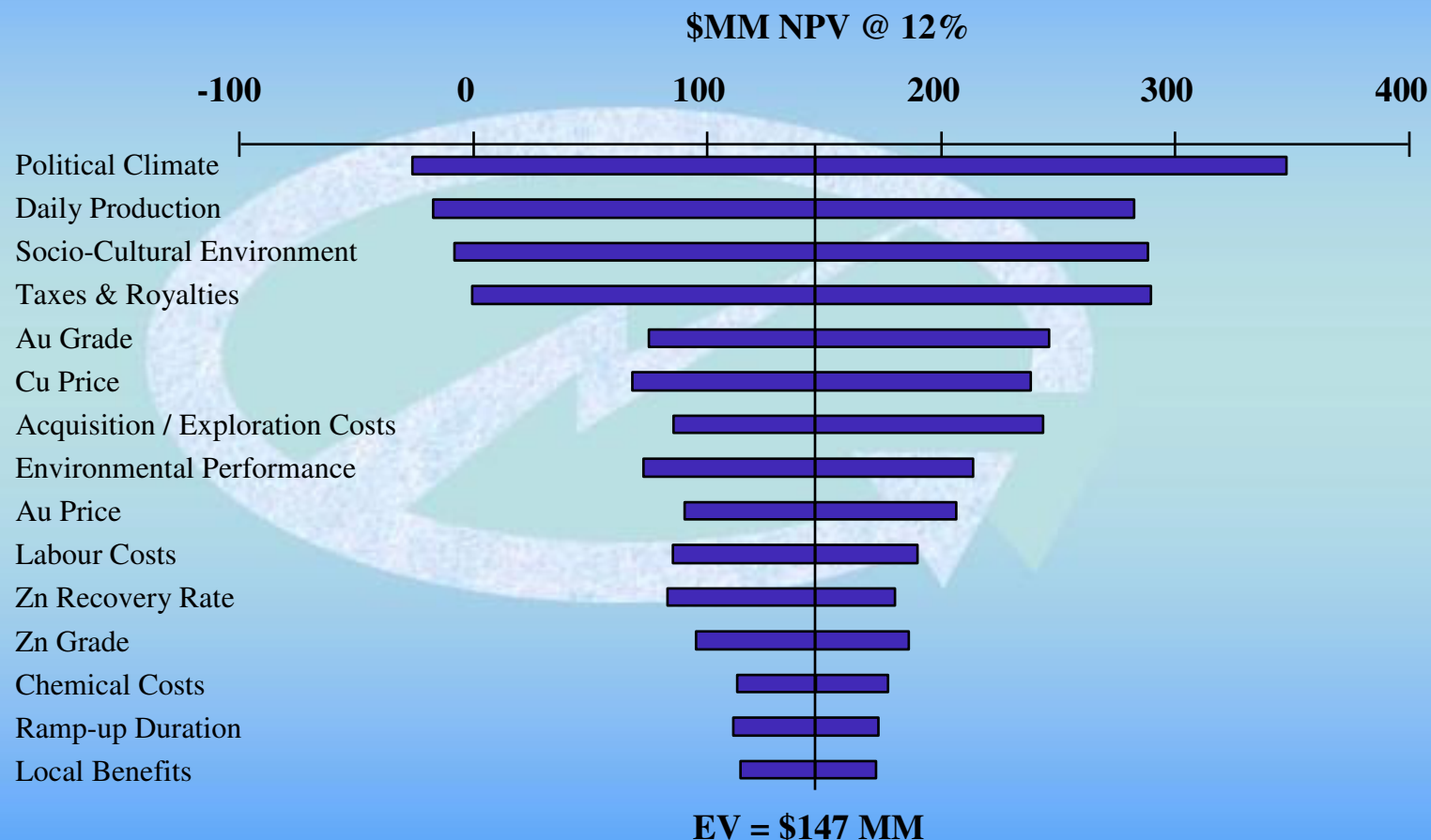
# Portfolio Management

## Cumulative Cash Flow



# Portfolio Management

*The Tornado Diagram highlights the key drivers for the option and identifies areas to focus mitigation efforts to ensure success*



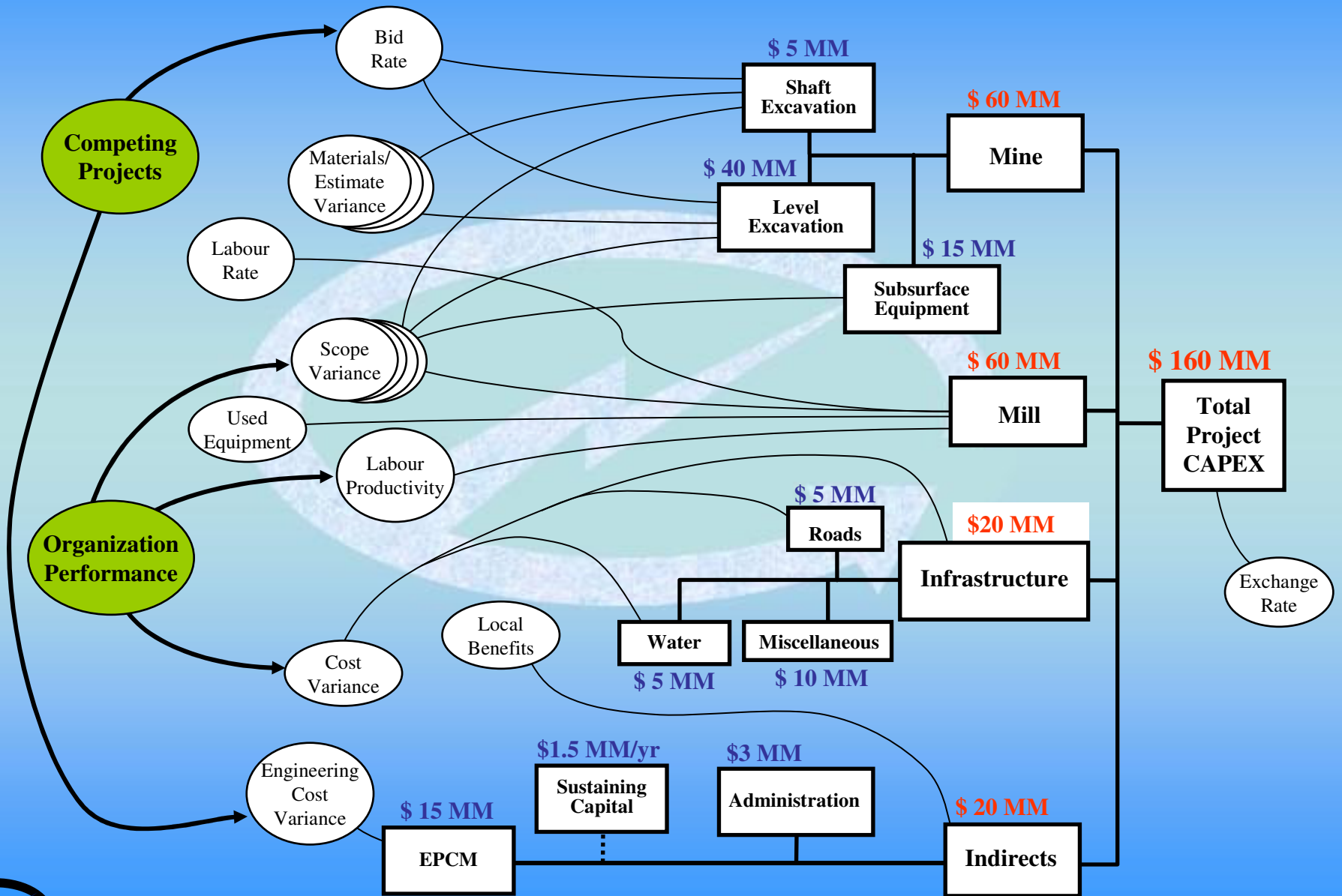
*NPV Canadian Case*

# *Mining Issues and Problems*

*During the Project Development phase the analysis should have more focus on the tactical level to ensure that the project is executed well.*

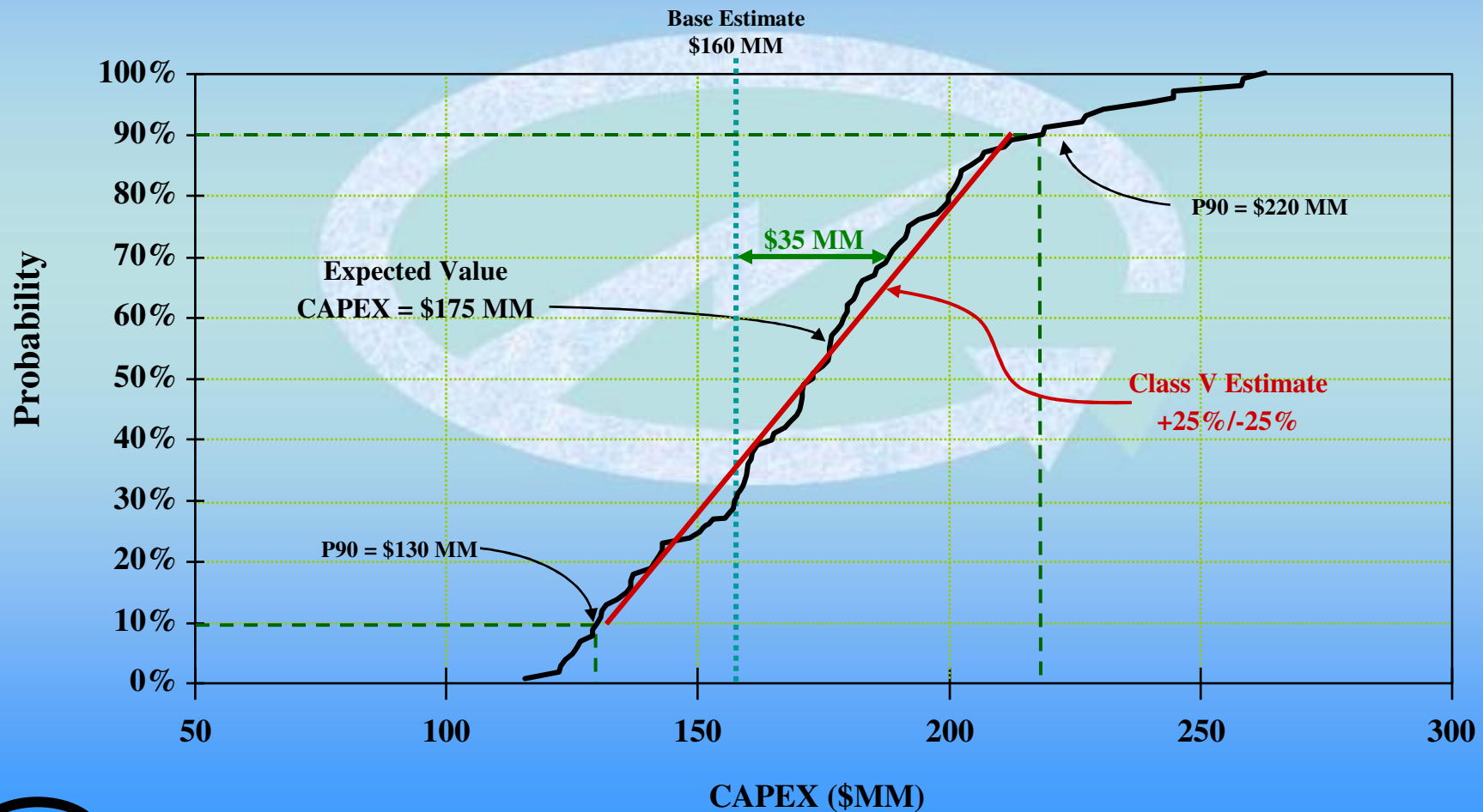
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# Development – capital cost for a mining project



## Development - CAPEX

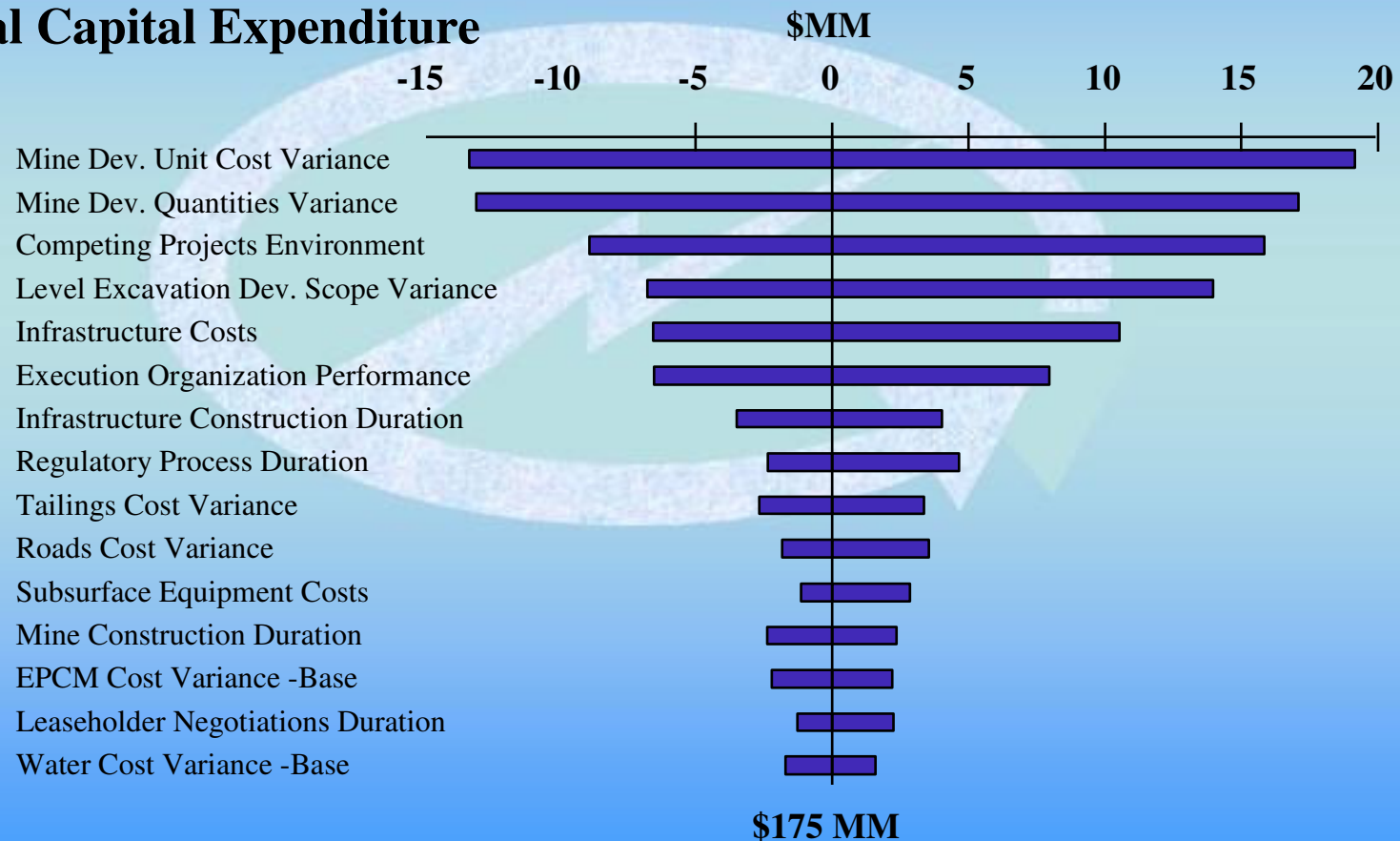
*The Cumulative Probability Distribution shows that \$35 MM (16%) contingency is required for a 70% confidence limit. The slope (uncertainty) in the curve approximates a Class V Estimate.*



## Development - CAPEX

*The range in in Capital Cost is largely due to uncertainty in Mine Unit Cost Variance, Mine Quantities Variance and Level Development Scope Variance.*

### Total Capital Expenditure



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## *Modern Day Applications of Risk Analysis to Mining Issues and Problems*

- ***Risk management is fundamental for accountability on corporate governance and on maximizing shareholder value.***  
*It begins with strategic definition and continues in a consistent manner throughout the project life cycle. The earlier risk management starts, the earlier you can avoid or mitigate risks and capture opportunities.*
- ***Risk Management ensures that there are no surprises.***  
*Documentation of assumptions and all risks. Communication of risk analysis results and the plan for managing those risks (avoid, accept, manage). The focus of efforts is on the underlying project risks.*
- ***Range Estimating is not Risk Analysis.***  
*Fully accountable risk analysis considers the specific uncertainties of a project, and incorporates these underlying risks into the project value. Processes that provide single-point outcomes or risk distributions based on the probability of fixed outcomes (decision trees, KT, range estimating) do not meet the definition of risk analysis.*
- ***“Ignoring risks to a project is not an option; important decisions will be made anyway, should they not be made with the best information available?”***  
*(Project Manager Today, October 2000)*