Analytics for Enterprise Risk Management

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Outline

- Overview of Enterprise Risk Management (ERM)

- Advanced Analytics for ERM
  - Compliance and Audit Risk Analytics
  - Operational Risk Management
  - Business Initiative Risk and Performance Management System
  - Analytics for Risk Integrated Enterprise Planning

- Future work
Overview of ERM
Enterpise Risk Management (ERM) - Defined

There are many definitions.

Enterprise risk management (ERM) in business includes the methods and processes used by organizations to manage risks and seize opportunities related to the achievement of their objectives. ERM provides a framework for risk management, which typically involves identifying particular events or circumstances relevant to the organization's objectives (risks and opportunities), assessing them in terms of likelihood and magnitude of impact, determining a response strategy, and monitoring progress. By identifying and proactively addressing risks and opportunities, business enterprises protect and create value for their stakeholders, including owners, employees, customers, regulators, and society overall.

ERM can also be described as a risk-based approach to managing an enterprise, integrating concepts of strategic planning, operations management, and internal control.

ERM is evolving to address the needs of various stakeholders, who want to understand the broad spectrum of risks facing complex organizations to ensure they are appropriately managed. Regulators and debt rating agencies have increased their scrutiny on the risk management processes of companies.

The key attributes are:

Integrated:
- ERM spans all lines of business and is governed at the enterprise level

Comprehensive:
- Spans all types of risks, across all business units, functions, processes, and systems

Pro-Active:
- Identifies and assesses risk events, plans and executes a response to them

Strategic:
- Provides transparent, risk-adjusted business performance management integrated into the business
- ERM focuses on risk events that impair the enterprise from fully achieving an objective
A well operated Enterprise Risk Management practice follows a general cycle of identifying risks, assessing and planning for the risk events, deploying and monitoring the solutions and reporting and reviewing the events as they occur. A feedback process then drives adaptation as warranted by going back to the identify & assess steps by validating, correlating, and prioritizing events, plans, and experiences.
The Value of Enterprise Risk Management

Why is ERM Important?
- Every public sector entity exists to realize value for its stakeholders.
- Value is created, preserved, or eroded by management decisions in all activities, from setting strategy to operating the enterprise day-to-day.

How does ERM deliver positive results?
- Strategic decisions informed with explicit consideration of risk
- Anticipation of issues and preparing for them in the execution of strategy
- Analyze ongoing operations and taking action to improve performance and increase consistency
- Effective monitoring of risks and provision of feedback to decision-makers at all levels

Cost of Risk

Cost of Risk
per $1,000 Operating Budget

- $20.00
- $19.00
- $18.00
- $17.00
- $16.00
- $15.00
- $14.00
- $13.00
- $12.00

IBM Research has Extensive Capabilities

In Analytic Techniques Required for ERM

- Deep expertise in predictive modeling, simulation analysis, stochastic optimization, and decision analysis
  - All are requirements for quantifying and managing risk & uncertainty
- Domain expertise in application areas that can benefit from advanced risk modeling
  - Infrastructure management, supply chain management, project management
- Skills to design and develop end-to-end analytic framework, including
  - Information management layer
  - Analytical modeling layer
  - User interface layer
IBM’s Risk Management Capabilities
*Organized around a Holistic View of Both Financial and Non-financial Risk*

<table>
<thead>
<tr>
<th>Risk Area</th>
<th>Imperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Risk</td>
<td>Understand risk exposure across silos in order to make rapid risk decisions consistent with your firm’s risk appetite</td>
</tr>
<tr>
<td>Fraud Risk</td>
<td>Instrument organizations to detect and interrupt financial crime patterns (Medicare claims, Social Security payments, etc)</td>
</tr>
<tr>
<td>IT &amp; Operational Risk</td>
<td>Anticipate and mitigate potential risk from failed internal processes, people or systems</td>
</tr>
<tr>
<td>Governance &amp; Compliance</td>
<td>Comply with voluntary and mandated regulations while differentiating your competitive position</td>
</tr>
</tbody>
</table>
Business Analytics for ERM – an organizational game-changer

The challenge:
- Many organizations “talk” about risks, make lists, define mitigation strategies use expert judgment (ALL IMPORTANT ACTIVITIES)
- A smaller number use hard data to quantify risk or support decision-making

Analytical tools can be used to:
- Quantify risks based on historical data, information from similar organizations, or data from third party organizations
- Use information about patterns of historical risks to predict future risks
- Build models to support investment decisions which take cost and risk probabilities into consideration
- Develop risk models that help when there is little or no historical information and while your organization begins the process of obtaining the data for the future
- Alternatively, provide more structured and objective approaches to elicit expert when there is no data
- Use behavioral models to study emergent behaviors – to help understand future risk modalities

IBM Research has created such analytics for our own business
Compliance and Audit Risk Analytics
Traditional methods of analyzing and managing compliance are predominantly manual and workload intensive

**Challenges with Traditional Approach**

- Analysis is performed with standard reports which are typically keyed to only a few parameters (such as vendor name) and may miss other significant factors
- Data analysis is manual and time consuming so scope of analysis may be limited
- It may be difficult to model the impact of changes to policies, resources or investments and obtain optimal ROI results out of various actions
- Lengthy report cycle time making it difficult to monitor compliance in real time

**GPS invested in a project with IBM Research to create a new capability utilizing predictive analytics to further automate the compliance management process.**
Compliance Analytics Tool is used to identify opportunities for improvement, select the optimal actions and track the results.

Compliance Analytics Tool (CAT)

- **Load Normalized Data**
  - Sources: PO & invoice history
  - Refresh with most current time period of history
  - (Planned: past forecast of compliance vs. actual)

- **Compliance Visibility**
  - Investigate overall compliance levels & trends
  - Focus on biggest non-compliance groupings

- **Identify Corrective Actions and Costs**
  - Select best options
  - Assign ownership
  - Secure commitment

- **Compliance Optimization**
  - Formulate compliance model
  - Run compliance optimizer
  - Prescribe actions for optimal returns

- **Client review & agreement**
  - Drive actions to secure desired outcomes

- **Compliance Dashboard**
  - Analytical report service
  - Scenario manager
  - Visualization of impacts

- **Track Results**

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How does the Compliance Visibility uncover opportunities for improved compliance?

- The Compliance Analytics Tool (CAT) uses user defined parameters to mine client transactional data to find **“clusters” of non-compliant transactions**

- Clusters of opportunity are identified **automatically** using advanced statistical techniques saving time and manual effort

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**Illustration of Clustering Technique**

- **Compliant**
- **Non-compliant**
Results of segmentation analysis on sample data

Segment 1 has the highest level of non-compliance at 89%, representing 92% of procurement spend.
Results of segmentation analysis on sample data

Segment 2 comprises of mostly low-dollar invoice transactions
CAT employs a mathematical optimizer to select best course of actions under constraints

- **Picking the best actions among a set is non-trivial**
  - Improving compliance in different categories yields different benefits
  - Benefits are a function of spend volume, room for improvement and costs

- **Modes of optimization**
  1. Maximize ROI while achieving overall compliance target
  2. Maximize ROI subject to a budget constraint

- **Output of optimization**
  - Best compliance actions to take
  - Compliance savings that are possible
  - ROI tradeoff analysis
Results of compliance optimization analysis of sample data

Compliance Summary

<table>
<thead>
<tr>
<th>Total Spend (USD)</th>
<th>Base Compliance (%)</th>
<th>Optimized Compliance (%)</th>
<th>Estimated Savings (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>447,256,353</td>
<td>51.0%</td>
<td>90.0%</td>
<td>33,715,701</td>
</tr>
</tbody>
</table>

Leading Entity Chart

Compliance BVI Chart

Summary by Leading Entity:

<table>
<thead>
<tr>
<th>Leading Entity</th>
<th>Spend (USD)</th>
<th>Non Compliance Spend (USD)</th>
<th>Compliance (As-Is)</th>
<th>Compliance (Optimized)</th>
<th>Estimated Savings (USD)</th>
<th>Business Value Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marketing</td>
<td>160,438,518</td>
<td>65,967,499</td>
<td>34.31%</td>
<td>99.58%</td>
<td>11,751,224</td>
<td>5.9</td>
</tr>
<tr>
<td>Real Estate Management</td>
<td>39,966,728</td>
<td>45,957,141</td>
<td>23.29%</td>
<td>78.60%</td>
<td>5,300,983</td>
<td>5.9</td>
</tr>
<tr>
<td>UNN001</td>
<td>80,228,548</td>
<td>32,313,317</td>
<td>59.72%</td>
<td>80.02%</td>
<td>7,382,872</td>
<td>10.0</td>
</tr>
<tr>
<td>Information Systems</td>
<td>123,979,189</td>
<td>23,278,723</td>
<td>91.22%</td>
<td>99.58%</td>
<td>3,300,425</td>
<td>3.7</td>
</tr>
<tr>
<td>Facilities</td>
<td>26,840,704</td>
<td>20,939,269</td>
<td>25.14%</td>
<td>78.98%</td>
<td>2,390,011</td>
<td>6.5</td>
</tr>
<tr>
<td>Logistic &amp; Reclamation</td>
<td>35,383,100</td>
<td>15,722,714</td>
<td>95.93%</td>
<td>90.00%</td>
<td>1,880,797</td>
<td>4.4</td>
</tr>
<tr>
<td>Store Operations</td>
<td>6,554,212</td>
<td>5,279,274</td>
<td>71.92%</td>
<td>81.44%</td>
<td>618,753</td>
<td>3.9</td>
</tr>
<tr>
<td>Merchandise &amp; Merchandising</td>
<td>6,541,041</td>
<td>4,367,273</td>
<td>33.23%</td>
<td>76.13%</td>
<td>455,138</td>
<td>4.4</td>
</tr>
<tr>
<td>Human Resources</td>
<td>5,075,355</td>
<td>4,046,820</td>
<td>20.33%</td>
<td>78.66%</td>
<td>461,158</td>
<td>4.5</td>
</tr>
<tr>
<td>Corporate General</td>
<td>3,420,277</td>
<td>1,825,824</td>
<td>46.74%</td>
<td>55.59%</td>
<td>58,806</td>
<td>5.4</td>
</tr>
<tr>
<td>Accounting</td>
<td>4,885,577</td>
<td>1,192,158</td>
<td>75.62%</td>
<td>80.00%</td>
<td>35,483</td>
<td>6.1</td>
</tr>
<tr>
<td>Summary</td>
<td>447,256,353</td>
<td>219,890,181</td>
<td>51.0%</td>
<td>90.0%</td>
<td>33,715,791</td>
<td>66.6</td>
</tr>
</tbody>
</table>

Observation:
Real Estate and Marketing are excellent candidates for compliance transformation, as they drive high non-compliance spend and yield a high return on investment.
CAT uses advanced IBM software assets in an innovative way to perform compliance analytics on client transactional spend data.
We’ve standardized the compliance decision rules; we are working to drive a common approach which is missing today.

### Standard Compliance Decision Rules

<table>
<thead>
<tr>
<th><strong>I. System Compliance: Is spend in right system?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Designated non-PO categories where PO’s are not expected &amp; related invoices treated compliant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>II. Process Compliance: Is spend flowing in right sequence?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Sourcing Indicator indicates by-pass/non-compliance or</td>
</tr>
<tr>
<td>B. PO date after Invoice date</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>III. Supplier Compliance: Is spend flowing to preferred suppliers?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>PO not tied to a SRM contract number; ie., we are not leveraging an existing contract with a preferred supplier</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>IV. Contract Compliance: Is contract pricing reflected in PO &amp; on Invoices?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract price = PO price = Invoice Price</td>
</tr>
</tbody>
</table>
Similar analytic techniques have been developed to audit claim data

- **Why it’s hard**
  - Most claim data is unsupervised, i.e., known examples of historical fraud and abuse cases that can be leveraged to tune fraud detection algorithms are not always available, or are have been identified based on tip-offs from informants or on complex and unusual domain expertise (“hunches”) that cannot be directly linked to patterns in the data.
  - The baseline patterns of conforming and fraudulent behavior evolve over time and can perplex auditors
  - Research expertise in statistics and data mining is needed to develop new statistical models that can handle the large amounts of high-dimensional data, not necessarily following a Gaussian distribution, to identify strong cases suitable for audit investigations with minimal false alarms
  - New methods are being developed that can adapt to evolving behavior

- **What we have done**
  - Developed and implement ed new statistical algorithms, leveraging SPSS where possible, to analyze claim data and distinguish “normal” or baseline behaviors from abnormal behaviors in complex and high-dimensional domains
  - Developed configuration templates for use by domain personnel for loading claim data and flagging and reporting potential problems.
  - Developed new reports to provide analysis results to investigators in a consumable way
  - Integrated new statistical and configuration capabilities into existing Fraud and Abuse Management System solution
Operational Risk Management
Operational Risk and Performance Management
Requires Quantification of Risks in Terms of Their Impact on
Key Business Metrics

Two Main Approaches

**Loss Distribution Approach**

Useful for modeling Low Frequency High Severity Losses, e.g.
Jumbo losses that can be estimated directly in terms of financial consequences, bypassing process-centric view

**Systems Approach**

Useful for modeling High Frequency Low Severity Losses, e.g. “Every-day” losses from IT Infrastructure disruptions
Directly links loss events to real business process consequences that in turn translate to financial loss
Systems Approach: Risk-based Strategic Decision Making Toolkit

- Prototype tool that
  - Allows a user to build a probabilistic network model linking risk (cause) to business process tasks (effect)
  - Allows for dependencies among factors
  - Provides a systematic way to think about risk in the context of an enterprise

- Helps achieve performance objectives by managing risks impacting key performance measures
More about the toolkit

- Allows definition of
  - Simple *process model*
  - *Risk factors* as conditions that influence the way an activity is performed
  - *Risk reduction actions* as actions that are taken to reduce the impact of risks on process performance

- Uses expert opinion to specify model input
  - Risk/process dependency structure
  - Risk and resource state likelihoods
  - Activity-level metric impacts

- Uses simulation to analyze and optimize process performance
  - Simulates business process performance as function of risk-dependent task metrics
  - Analyzes sensitivity of performance to different risks and risk categories
  - Uses heuristic search methods to select optimal sets of risk reduction actions
Risk Elicitation Tool Enables Easy Capture and Aggregation of Risk Likelihoods and Severities from Multiple Experts, Allowing for Interdependencies Between Risks
Case: Helping the FAA Enhance Cyber Threat Information

CSMC = Cyber Security Management Center

Risk Management is an important IT Governance concept and an essential prerequisite for successful security

Using the Process-based approach to enhance incident ticket information, create actionable cyber threat information, and establish operational relevance

Risk
- Threat
- Vulnerability
- Consequence

Dot - Threat - Vulnerability - Consequence

FAA CSMC

Protection Detection Response Ticket

Problem Definition

So What?

What to do?

Business Process Management support for critical processes

Technical Profile

Operational Profile (operational impact)

Local Impact

Enterprise Impact

Mitigation Options

Express via
- People
- Process
- Technology
Business Initiative Risk and Performance Management System
Risk and Performance Management System is a tool that leverages business analytics to provide three main capabilities designed to help IBM achieve performance objectives for business initiatives.

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Analysis/Analytics</th>
<th>Implications</th>
</tr>
</thead>
</table>
| **Identify and Quantify** | - Identify performance factors and root causes, and their impact on initiative performance  
- Capture up to date lessons learned from initiative teams & functions | - Generate quantifiable explanation of what happened in a quarter and allows for comparison across initiatives  
- Real-time feedback on mitigation actions and best practices being driven by project teams |
| **Anticipate (New & In Flight Initiatives)** | - Anticipate potential risks and estimate their performance impact based on initiative characteristics | - Support smarter planning and execution leveraging new lessons learned each quarter |
| **Manage (Portfolio)**   | - Identify cross-IBM and within-function initiative performance trends and quantify their impact on initiative and portfolio performance | - Encourage fact-based, analytically driven business discussions about key drivers of performance  
- Identify and manage performance factors throughout the initiative lifecycle |
We use a risk taxonomy to identify and quantify factors impacting IBM’s initiative performance.

### Example Sub-section of “Tree”

<table>
<thead>
<tr>
<th>Layer-1</th>
<th>Layer-2</th>
<th>Layer-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>Enablement</td>
<td>Enabling IBM Sellers</td>
</tr>
<tr>
<td>Development</td>
<td>Capacity</td>
<td>Hiring Approvals</td>
</tr>
<tr>
<td>Fulfillment</td>
<td>Execution</td>
<td>Retention</td>
</tr>
<tr>
<td>Finance</td>
<td>Incentive</td>
<td>Sales Cycle Time</td>
</tr>
<tr>
<td>Marketing</td>
<td></td>
<td>Deal Size</td>
</tr>
<tr>
<td>Strategy</td>
<td></td>
<td>SaaS Incentives</td>
</tr>
</tbody>
</table>

### Features
- Based on historical initiatives
- Oriented by business function to drive actions
- Multi-layer hierarchy provides increasing levels of granularity
- Provides a highly structured framework to rigorously identify and track initiative issues

… 850+ unique tree leaves / 5-layers
We use an initiative “fingerprint” to identify, prioritize and recommend mitigation actions

<table>
<thead>
<tr>
<th>Initiative Fingerprint</th>
<th>Allowable Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Geographic scope</td>
<td>Global, Geographic, Regional</td>
</tr>
<tr>
<td>2 Industry specific?</td>
<td>Y/N</td>
</tr>
<tr>
<td>3 Strategic Intent</td>
<td></td>
</tr>
<tr>
<td>4 ...</td>
<td></td>
</tr>
<tr>
<td>5 ...</td>
<td></td>
</tr>
<tr>
<td>6 ...</td>
<td></td>
</tr>
</tbody>
</table>
The methodology determines the probability and financial impact of potential risks by evaluating the initiative “finger-print”

Determining the chance a risk will occur...

...and impact of integration risks

**A** Counting historical occurrences predicts a 5.6% probability (i.e., insensitive to initiative finger print)

**B** However, risk probability increases to ~75% for initiatives with Regional Scope that are Industry Specific

**Revenue impact estimated by allocating performance variance relative to target across risk factors, measured via risk capture process**

**Collection of Risks**

<table>
<thead>
<tr>
<th>Historical Initiatives</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>∆PORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-1</td>
<td>0</td>
<td>0</td>
<td>1*(-15%)</td>
<td>0</td>
<td>1*(-15%)</td>
<td>-30%</td>
</tr>
<tr>
<td>Q-2</td>
<td>0</td>
<td>1*(-10%)</td>
<td>0</td>
<td>0</td>
<td>1*(-10%)</td>
<td>-20%</td>
</tr>
<tr>
<td>Q-3</td>
<td>1*(-5%)</td>
<td>0</td>
<td>1*(-5%)</td>
<td>0</td>
<td>0</td>
<td>-10%</td>
</tr>
<tr>
<td>Q-N</td>
<td>0</td>
<td>1*(-20%)</td>
<td>1*(-20%)</td>
<td>0</td>
<td>1*(-20%)</td>
<td>-60%</td>
</tr>
</tbody>
</table>

**Conditional Impact (CI)**

| Net-Impact | -5% | -15% | -13.3% | 0%  | -15% | N/A   |

Net-Impact is the average financial impact of a risk factor (i.e., driven by the chance a risk will occur and the impact if it occurs)
Risk and Performance Management System Advanced Analytics

- **Technical Innovations**
  - Defined taxonomy and process to categorize and capture risks associated with initiatives
  - Built novel statistical models for predicting potential initiative risks over their lifecycle, based on historical data
  - Developed standardized methodology for estimating financial impact of different initiative performance factors
  - Built an enterprise system to bring together descriptive & predictive analytics into a seamless solution

- **Key analytic components**
  - Core set of **statistical models** to predict initiative integration risks and estimate their potential financial impact, at an individual initiative and a initiative portfolio level
    - Initiative descriptor-based regression models for preliminary initiative filtering
    - Boosted hierarchical classification trees to predict and prioritize risks as a function of initiative descriptor combinations
    - Time series regression methods updated with expert-specified weights to link risks to financial performance
  - Comprehensive **Cognos reports** to provide views of predicted risks, financial impacts, and mitigation actions
    - Individual initiative views of predicted high impact risks
    - Portfolio views of expected financial performance
    - Temporal views of initiative risks over the initiative lifecycle
    - Suggested mitigation actions
  - ....
## Portfolio Risk & Investment Modeling Engine

*For Risk-aware Assessment of Enterprise Initiatives Portfolios and Resource Allocation*

<table>
<thead>
<tr>
<th>Client</th>
<th>IBM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenge</td>
<td>A division within IBM faced the challenge of effectively managing its product development pipeline, which is a complex portfolio of various programs and interdependent projects that target various workloads, in the face of significant risk associated with estimates for revenue, development effort sizing and timing, and selling expenses. They are embarking on a transformational effort to overhaul the Portfolio Management Process, which needs Analytics as a foundational piece to enable risk-adjusted decision-making.</td>
</tr>
</tbody>
</table>

### Inputs

1. Financials, e.g. Business cases
2. Risk assessment, Probability Distributions
3. Objectives
4. Interdependencies, Business Rules, Constraints
5. Qualitative tags, e.g. customer segment, workload quadrant

### Solution

Research developed a stochastic optimization tool, PRIME, which enables Risk Assessment, Risk Quantification, and Risk-adjusted stochastic Portfolio Analysis

### Hypothesized Benefits

- Achieve 5% YTY Revenue growth and at least a 10% YTY Pre-Tax Income growth, with a 95% confidence
- Maximize Revenue and PTI while reducing YTY DE by x%

Can I meet my financial targets if I invest x% in growth initiatives, or y% in a market segment?...
Analytics for Risk Integrated Enterprise Planning
Analytics for Risk Integrated Enterprise Planning

- **Business Drivers**
  - *Increased volatility* in the market is driving a growing desire to *incorporate risk into planning* and requires decision makers to understand uncertainty as it relates to enterprise plans before closing/executing on them. Interest in financial analytics is growing.
  - Business executives need capabilities that are *consumable and integrated* within enterprise systems to ease application of sophisticated statistical techniques and leverage the power of predictive analytics to assist in planning and decision making. Simplification rather than complexity is key.

- **Leading companies**
  - Have evolved from ad-hoc, manually intensive financial planning and analysis to *forward-looking driver based modeling*
    - Driver Based Modeling
    - Predictive modeling based on scenario analysis
    - Action plans created based on risks and opportunities
The CFO Executive Board suggests embedding Risk Management into Enterprise Planning

- As the complexity and volume of risks increase, unexpected risk events occur more frequently making it difficult to accurately predict the future. Not only are fat tail events more likely than assumed, but organizations are unprepared for them.
- We typically underestimate the likelihood and impact of (supposedly) outlying events.
- Develop a range of possible scenarios with the business, and help operations to isolate critical business drivers which indicate a scenario is playing out.
- Acknowledge the degree of cyclical the investment reflects (e.g., if, cash flow visibility is variable under a recessionary contraction), document these assumptions in the investment proposal and map out how that project might proceed under various scenarios.
Gartner’s Maverick Research: Business Simulation and Modeling

- ...growing importance of complex models harnessing complex statistics that can be used by non-analysts to simulate highly complex business problems and generate any kind of scenario or simulation they need to help them make better decisions

- Organizations will start linking planning systems together across the enterprise using an enterprise metrics framework consisting of leading operational performance indicators linked to lagging financial measures. This will become the foundation for a comprehensive planning and simulation environment
Analytics for Risk Integrated Enterprise Planning

- **IBM’s Approach**
  - Embed statistical forecasts in planning tools to assist users in setting baselines
  - Incorporate capability to understand risks associated with the plan, given uncertainties such as market conditions and competition
  - Provide business leaders with ability to make risk-aware decisions in the face of uncertainty using probabilistic range forecasting
  - Provide ability to identify key sensitivities to operating levers in order to drive insightful actions

- **Uncertainty Analysis for Enterprise Planning**
  - Reflect probabilistic nature of uncertainty in enterprise planning by enabling range and/or distributional projections for key assumptions
  - Use Monte-Carlo method to simulate thousands of experiments to explore and understand the universe of possible outcomes and their likelihood of occurrence
  - Quantify variability in the planned outcomes

- **Sensitivity Analysis for Enterprise Planning**
  - Enable specification of best and worst case values for key assumptions (i.e. the expected range of possible values)
  - For one assumption at a time, use Monte-Carlo method to sample values spanning the range to explore the corresponding range of impacts on key performance metrics
  - Identify sensitivities of business outcomes to key assumptions through, e.g., a tornado diagram showing business outcomes prioritized by their variation in response to the range of assumption values

- **Business Optimization for Enterprise Planning**
  - Input target values for business outcomes and appropriate constraints
  - Use Monte-Carlo method to simulate sets of scenarios designed to narrow down the space of assumption values that meet the outcome criteria
  - Identify optimum values of key assumptions to satisfy business outcomes

- **Statistical Hierarchical Forecasting for Enterprise Planning**
  - Exploit the hierarchical nature of the data.
  - Generate consistent multilevel forecasts for planning. Optimized algorithms determine appropriate levels for forecasting – top down, bottoms up, middle out.
  - Spread the results to the entire cube. Aggregate up and allocate down.
Provide statistically-generated forecasts to supplement human generated projections for enterprise planning

**Statistical HIERARCHICAL Forecasting**

a. Exploit the hierarchical nature of the data
   ▶ Planning assumptions are multi-dimensional
   ▶ … with volumes across multiple enterprise hierarchies.

b. Generate consistent multilevel forecasts for planning
   ▶ Optimized algorithms determine appropriate levels for forecasting
   ▶ … to provide accurate baselines for planning and budgeting

c. Spread the results to the entire cube
   ▶ Aggregate the forecasts up the selected level.
   ▶ Spread the forecasts down to the leaves
Allow for uncertainty in planning assumptions enables identification of most likely outcomes and variability in the plan.

**UNCERTAINTY Analysis**

a. Reflect probabilistic nature of uncertainty in enterprise planning
   - Planning assumptions may take on a spectrum of values
   - … with different probabilities

b. Simulate thousands of experiments
   - Monte-Carlo method to explore and understand the universe of possible outcomes
   - Simultaneous changes of multiple parameters (multi-dimensional simulation)
   - Potential for correlated changes

c. Identify variability and volatility in the planned outcomes
   - What is the distribution and variability given uncertainty in the market
   - Comparison of most likely values of planned outcomes to baseline
Enable sensitivity analysis in the planning model allows identification of key assumptions driving proactive actions

**SENSITIVITY Analysis**

a. Identify key assumptions
   - Based on subject matter expertise identify key assumptions
   - …and understand ranges (best / worst case)

b. Simulate independent experiments
   - Monte-Carlo method to explore and understand the universe of possible outcomes
   - Independent changes to each parameter (multi-dimensional simulation)
   - Potential for correlated changes

c. Identify key sensitivities and distributions
   - Which key metrics is affected the most by a given assumption?
   - Which assumption affects a given metric the most?
Identify ranges and variability on key assumptions permits an organization to optimally drive toward financial targets

**OPTIMIZING the Plan**

a. Identify key business outcomes and corresponding financial targets
   - Elicit constraints on key assumptions and targets to reflect real world business operations.
   - …and provide ranges (minimum / maximum allowable values) on the assumptions and targets.

b. Simulate scenarios over the range of assumptions
   - Use the Monte-Carlo method to intelligently simulate over the search space, incorporating business constraints
   - Explore resilience of targets to key assumptions in different regions of the search space.

c. Identify scenarios compliant with business targets
   - Rank order the scenarios to understand possible outcomes.
   - Determine the allowed variations in key assumptions to optimally meet business goals.
Next generation Strategic Risk toolkit: **Risk Modeler** will develop a structured, consistent and repeatable process for quantifying strategic enterprise risks and linking them to the enterprise plan.

- Common risk framework
  - Library of risk factors
    - Leverage of Open Pages, where possible
  - Templates for risk scenarios based on Bayesian Networks
  - Distributed expert elicitation of probabilistic risk input
  - Specification of mitigation actions

- Complex scenario analysis / optimization
  - Efficient simulation-based optimization over high dimensional space

- Novel visualizations to communicate about risks
  - Risk maps linked to key enterprise business processes
The Strategic Risk Modeler provides a framework to elicit expert knowledge and aggregate it to a comprehensive risk model.

1. RISK IDENTIFICATION
   a. Obtain verbose Risk description
   b. Identify key risk variables and establish corresponding probability density functions (p.d.f.’s), reflecting uncertain nature of the Risk

2. RISK PROFILE ELICITATION
   a. Build an influence map reflecting how key risk variables interact with each other and the 2015 Roadmap Model assumptions
   b. Turn the influence map into Bayesian Belief Network by eliciting the conditional probabilities affecting states of the nodes
   c. Propagate key risk variable p.d.f.’s through the network to infer the behavior of the 2015 Roadmap Model Assumptions under Risk

3. SIMULATION & IMPACT ANALYSIS
   a. With inferred behavior of 2015 Roadmap Model Assumptions, perform a simulation run (1000+ experiments)
   b. Analyze and understand the space of possible outcomes calculating, e.g.:
      - Expected gaps to target (under unmitigated Risk)
      - Likelihood of goal attainment for specific metrics
      - Variance of metrics of interest
      - Metric values attainable with a specified confidence level

4. MITIGATION & OPTIMIZATION
   a. Identify mitigation actions
   b. Quantify mitigation actions acting separately or in concert
   c. Given mitigation action costs, optimize for maximum impact at minimum cost
Risk Modeler statistical analysis exposes the nature of risk as an uncertainty in the outcome and facilitates decision making on the way to an optimal one.

Sample results

- The mean of the Cost distribution (under Natural Hazard Risk) is $265M, which is $46M (15%) below the baseline.

- Standard deviation of the distribution of the Cost (under Natural Hazard Risk) is $60M, indicating that absent risk mitigation actions the likely range for Cost is from $205M to $325M.
Future work
What’s next?

- **Solutions**
  - Analytics for Enterprise Risk Management
  - Systemic Risk Analysis Platform
  - Supply Chain Risk Management
  - ..... 

- **Core research**
  - Robust statistical methods/Robust optimization for uncertain data
  - Reasoning with imprecise probabilistic information
  - Adversarial risk analysis
    - Cyber security
    - Critical infrastructure security
  - Communication of risk and uncertainty
  - .....
Thank you!