Advancements in Implementing Operational Risk, Stress Testing and Risk Appetite for ORSA

Institute of Actuaries of Japan

Joshua Corrigan
Principal, Milliman

5 March 2014

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Contents

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The Evolution of ERM

Section 1

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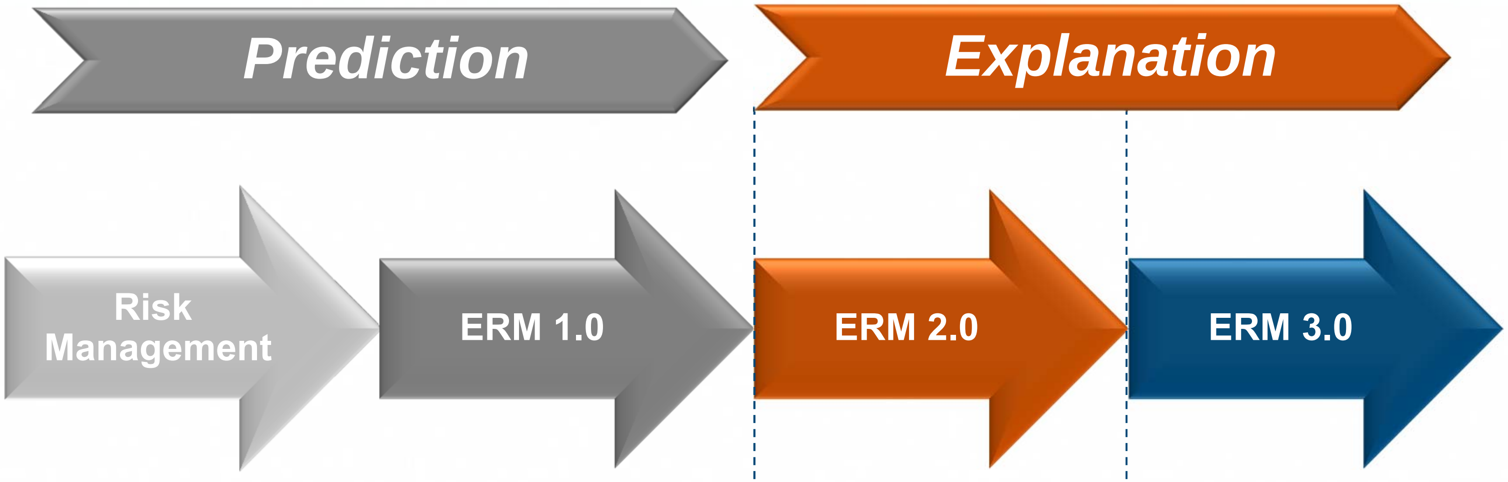
The Evolution of ERM



The Dawn of Risk Management

Basic analysis of individual risk types
Attempts to understand variation in key factors.

The Era of ALM and Financial Risk

Development of ALM to capture balance sheet interactions.

Acceleration of financial risk techniques.

Results aggregated to the enterprise level.

The Era of Rewa and Governanc

Perspective of risk related to reward.

ORSA

Concept of risk appe

Focus on managemen well as measureme

The Era of Culture and Resilience

Embedding of risk and understanding it through culture.

Resilience concept emerges.

Focus on risk dynamics and interrelationships

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ORSA Becoming a Global Standard

What business decisions do we need to take given we are exposed to risk and uncertainty?

Risk

P&L and Balance Sheet Modelling

Uncertainty

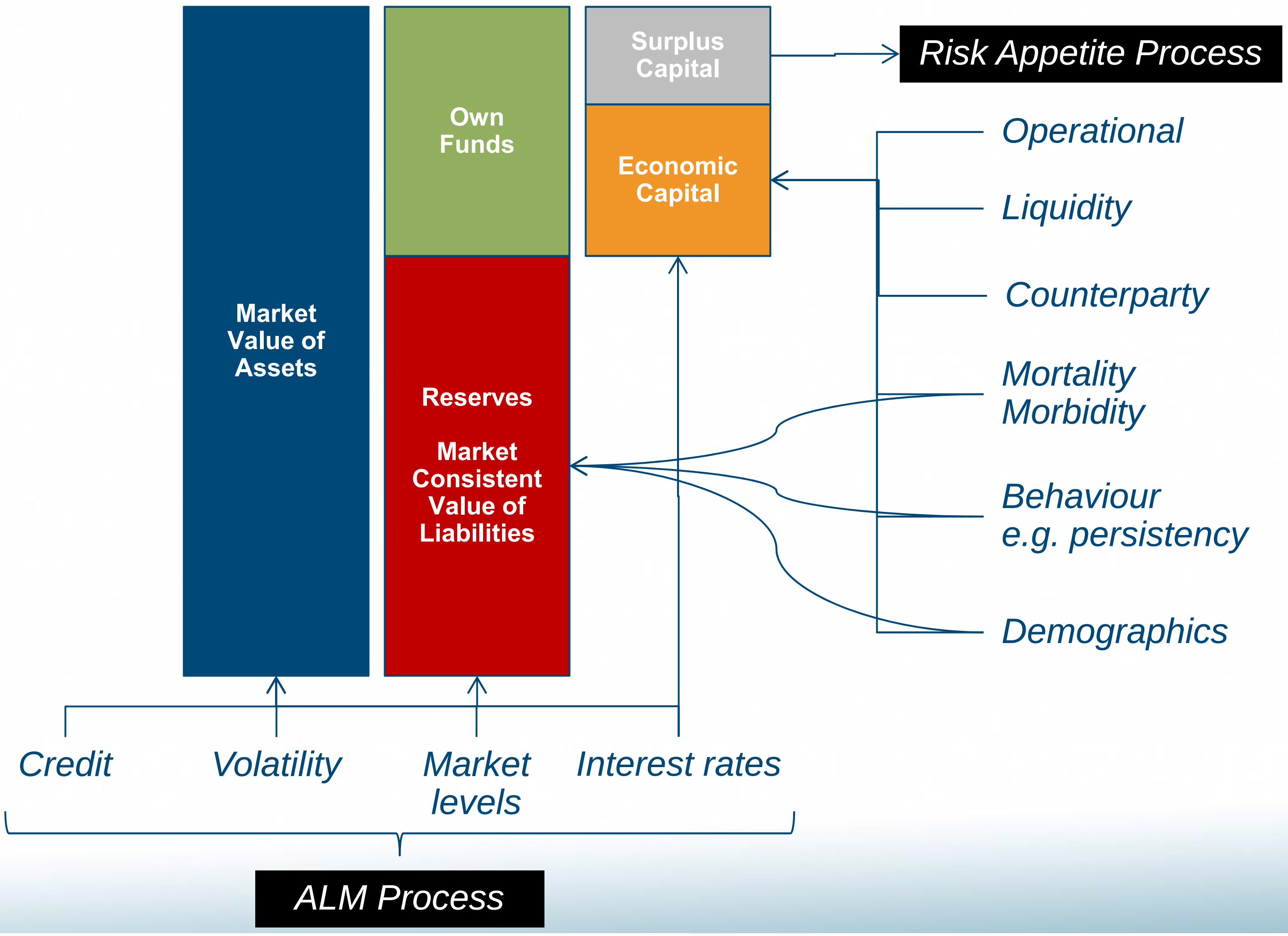
Scenarios

Business Decisions

Embedding

ORSA: Balance Sheet Risk Management

Components and Inter-relationships



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ORSA: P&L Risk Management

Understanding the drivers of P&L uncertainty

	Sales	*Sustainability of growth Quality of business → Multiple interrelated drivers of demand (e.g. behaviour, economics)*
Alignment of incentives b/w customer, distributor, manufacturer → Persistency risk, churn	Distribution Costs	
	Manufacturing Costs	*Quality of u/w and pricing process Experience of demographic, market and behavioural risks*
Operational capacity, availability, utilisation, productivity Economic, market drivers	Expense Costs	
	Operational Risk Costs	*Direct hit to the bottom line Need to manage these risks (e.g. fraud, mis-selling, mis-pricing)*
Earnings and margin uncertainty driven by complex interaction between above factors	Operating Profit Margins	

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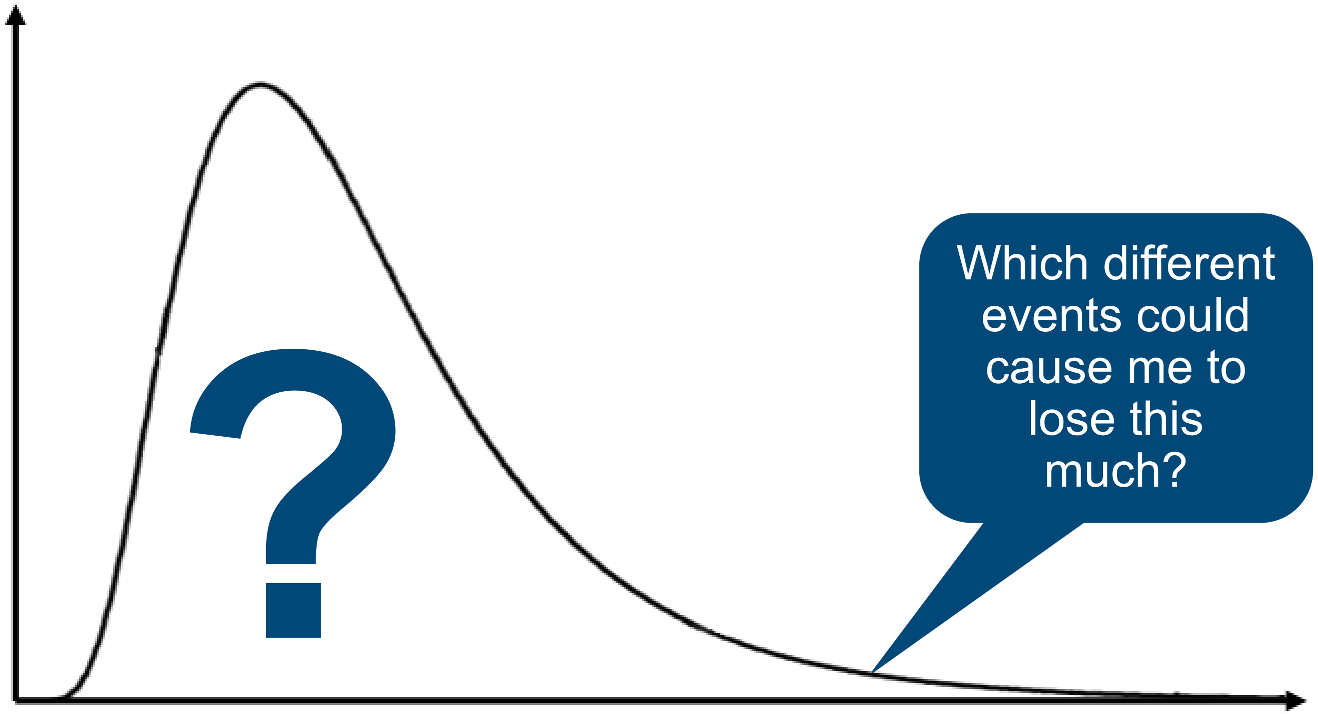
Prediction ≠ Explanation

Need to move from pure statistical to causal risk frameworks



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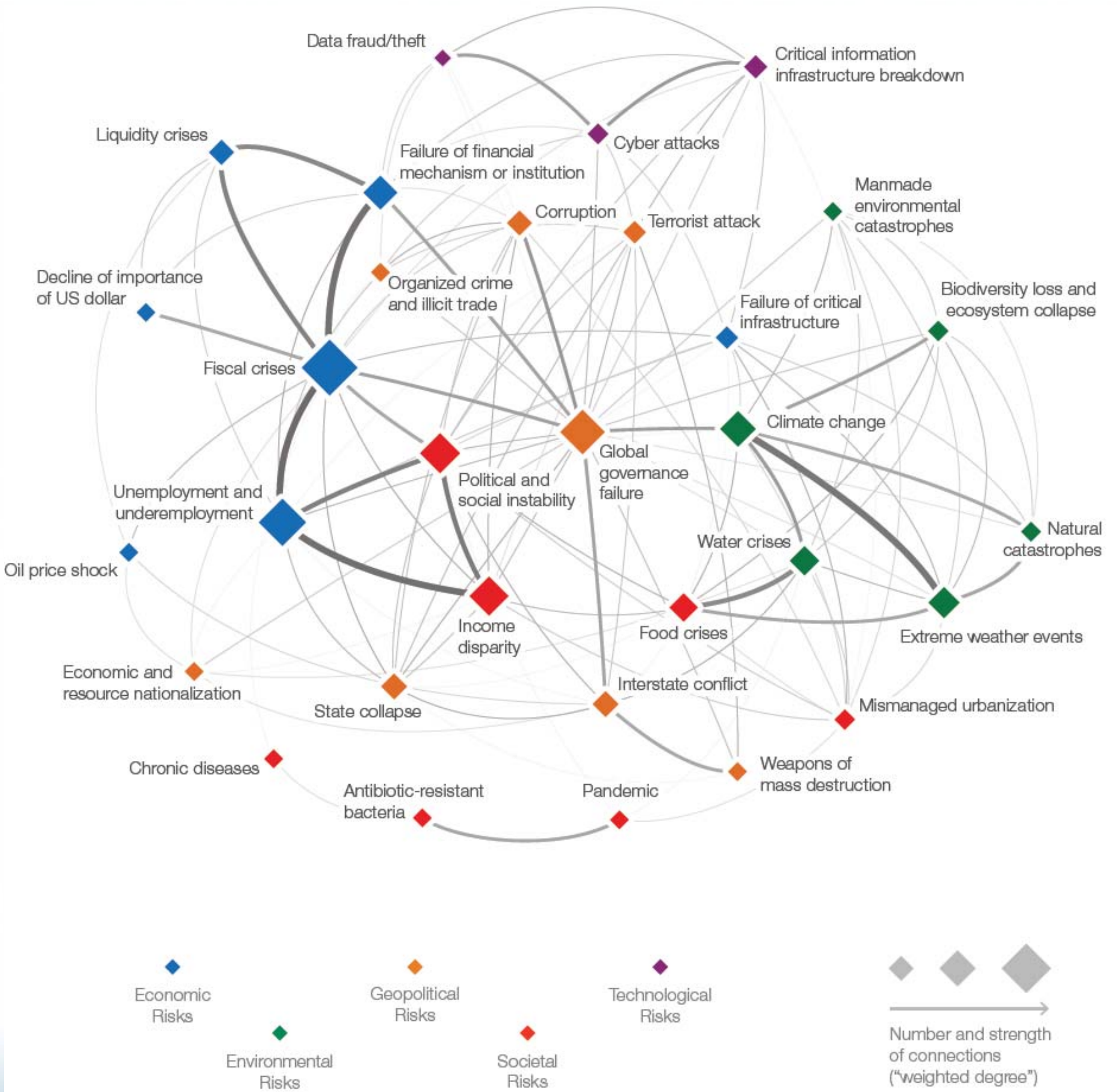
Complexity / Connectivity / Emergence



WEF Global Risks Map 2013

Complex systems mean you can't understand the whole by only studying the sum of the parts.

It is the inherent and dynamic relationships between risks, causal drivers and outcomes that is key.

Simple measures of dependency such as linear correlation are typically misleading

Risks relating to complex adaptive systems exhibit emergent properties

Current and Emerging Challenges

ERM 2.0

- Risk governance
- Risk processes
- Operational risk
- ORSA pillar 2
  - Strategic / holistic risk assessment
  - Operational risk
  - Risk appetite
  - Scenario / stress testing
  - Risk interdependencies
  - Risk reporting
- Operational risk systems

ERM 3.0

- Resilience
- Risk culture
- Behavioural risks
- Emerging risk
- Reverse stress testing
- Risk dynamics and inter-relationships through systems science
- Causal light models focused on explanation, not just prediction
- Risk engagement with business
- Integration of predictive analytics

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Technical Developments

What you know

Section 2a

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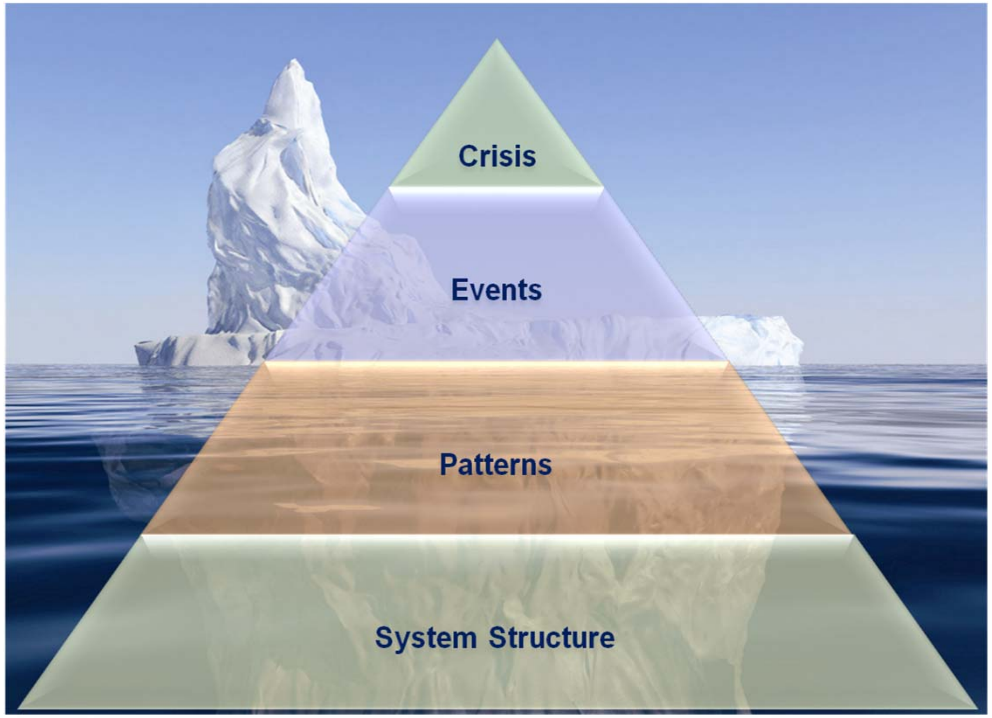
Companies are Complex Adaptive Systems

Risk is an undesirable outcome of a complex system



Traditional Risk Management Frameworks

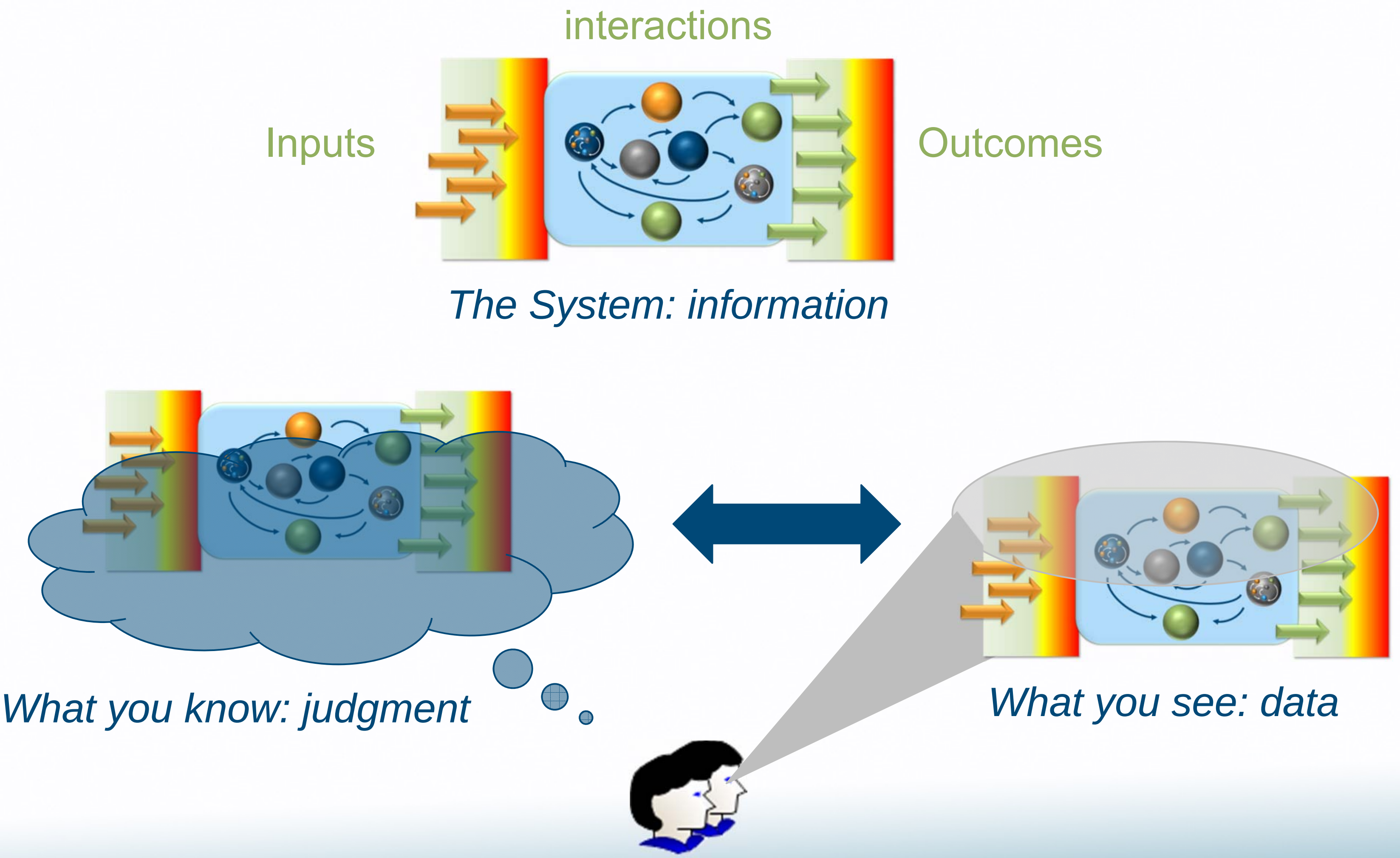
Statistical models, assuming constant drivers
Registers assuming single characteristics
Scenarios “imagined”
Emerging risks by spotting events

Frameworks based on complex systems

Descriptions of risk profile taken holistically
Scenarios derived from risk profile
Models integrate all types of information
Emerging risks spotted early from system

Risk management can be hard if looked at it through the wrong lens

Data is only part of the information set



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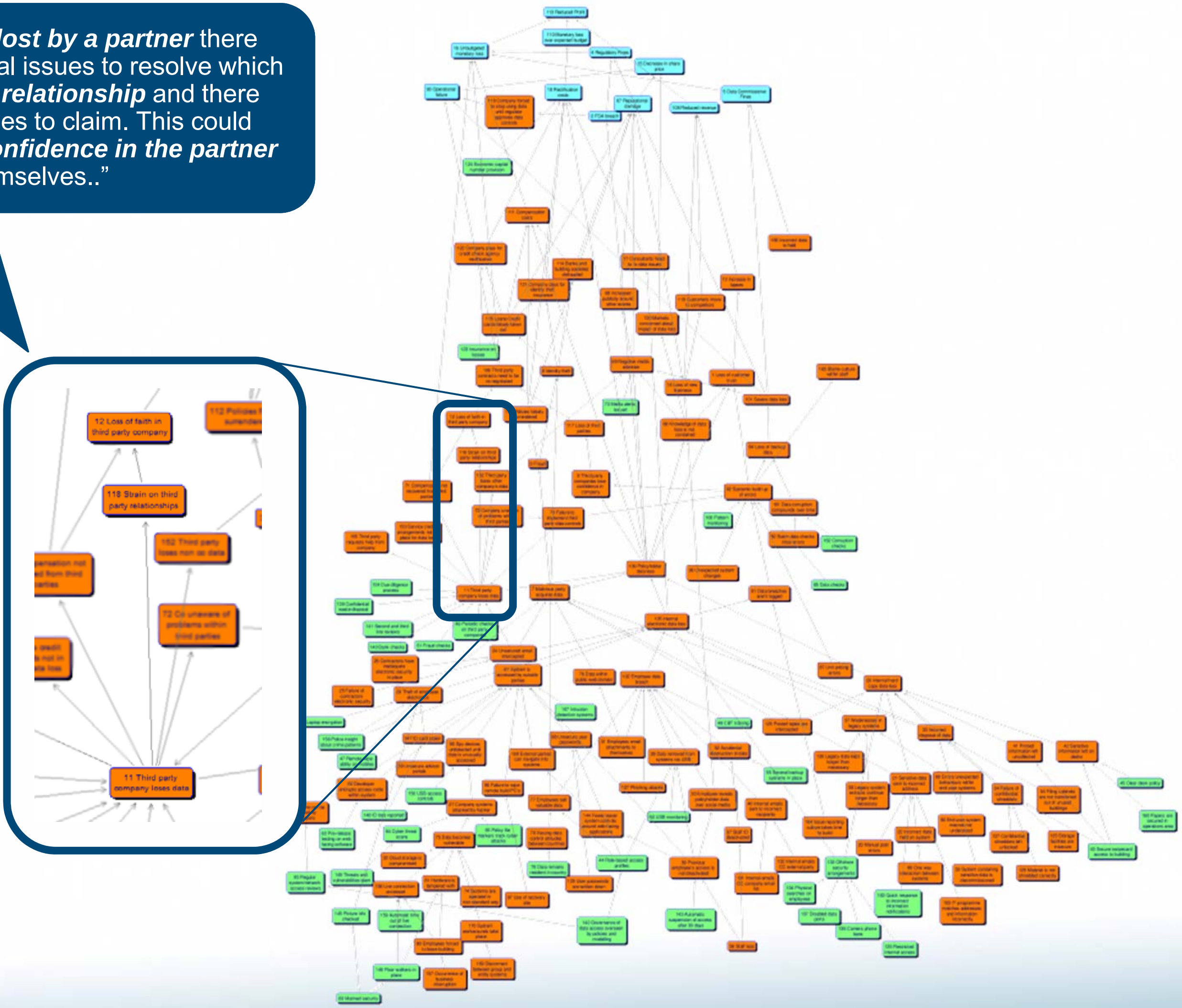
Describing the System

"If the ***data was lost by a partner*** there would be contractual issues to resolve which would ***strain the relationship*** and there would be damages to claim. This could cause a ***loss of confidence in the partner*** themselves.."



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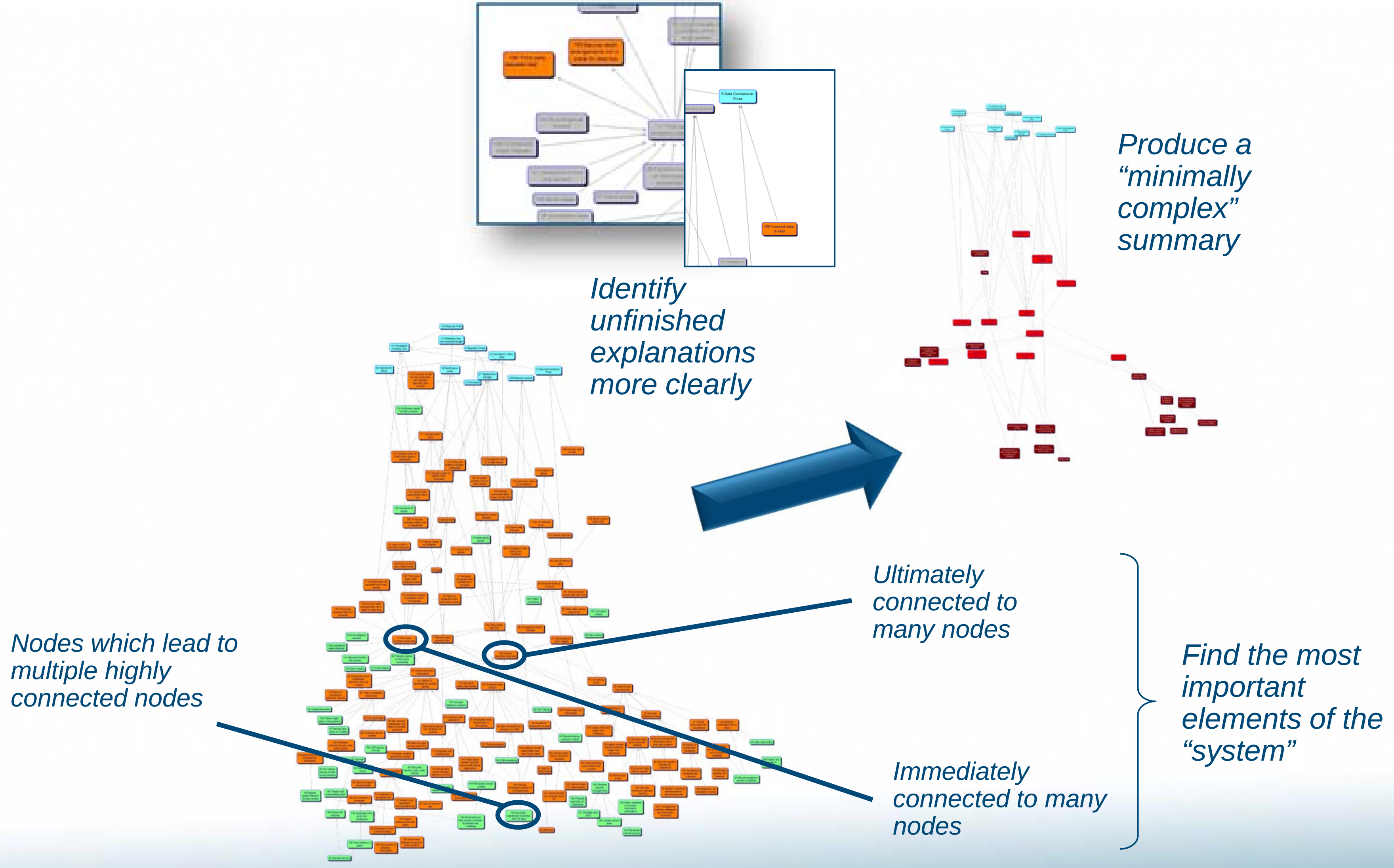
Cognitive Analysis



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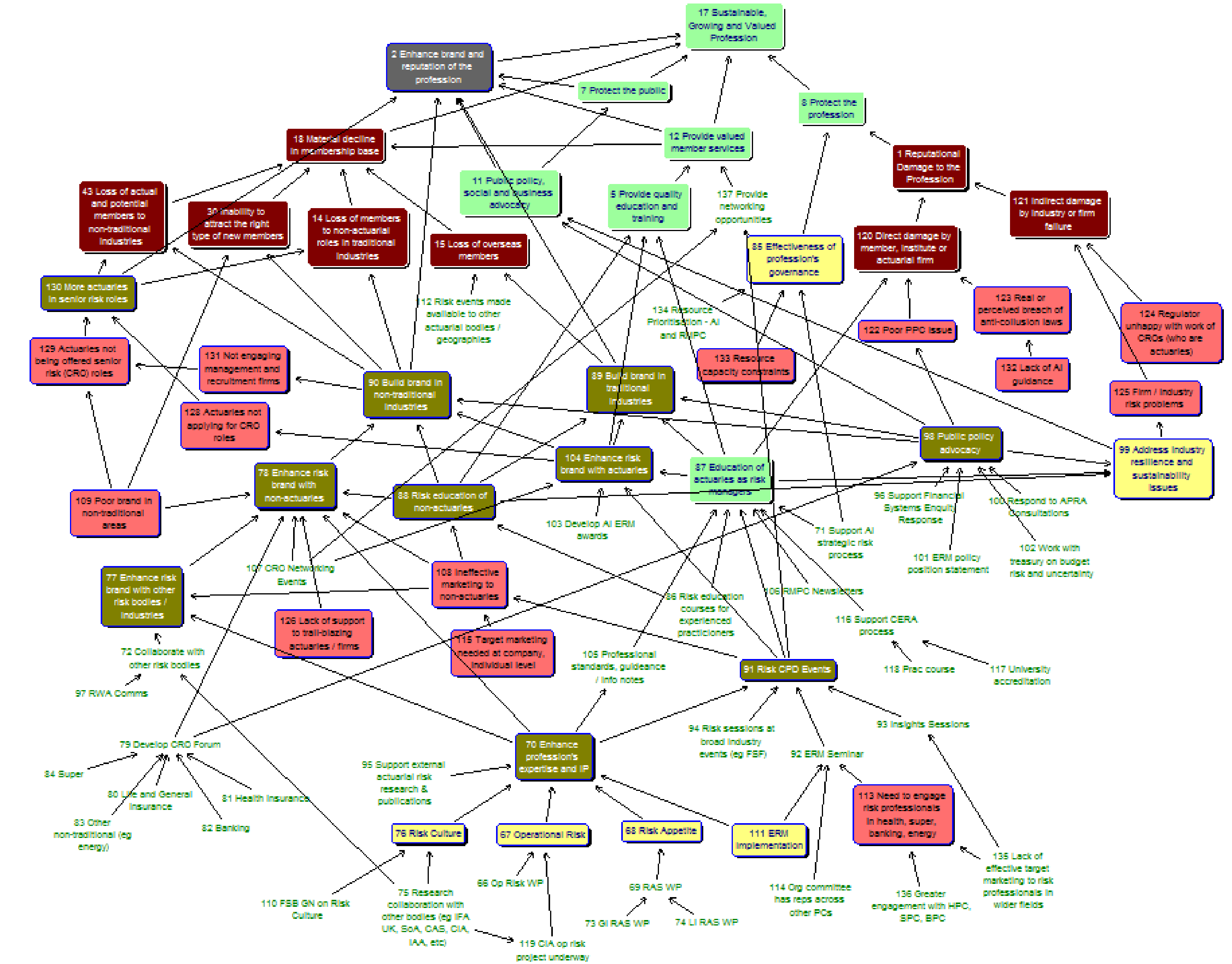
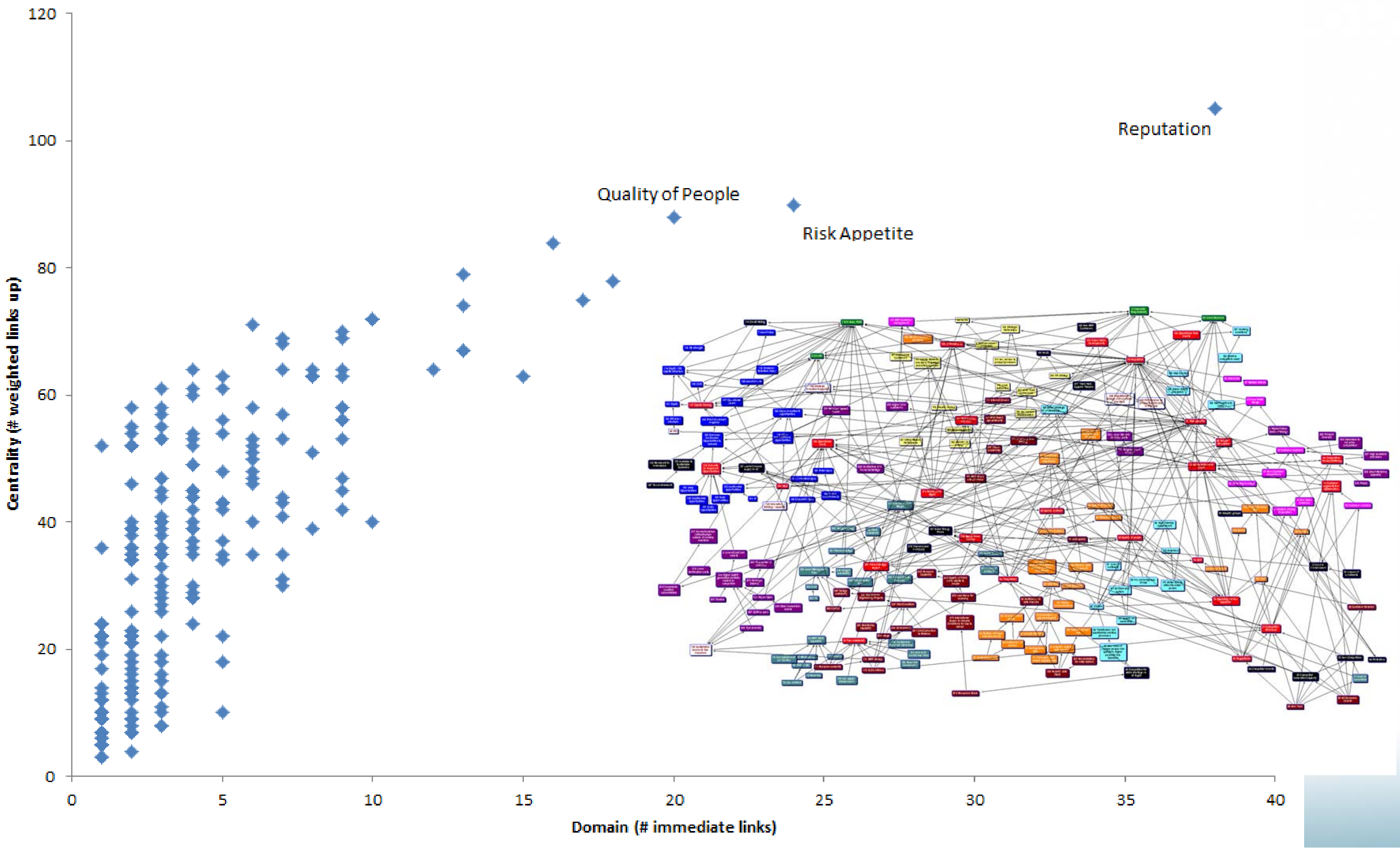
What are the Risks to the Actuarial Profession?



Relative Importance of Risk Drivers



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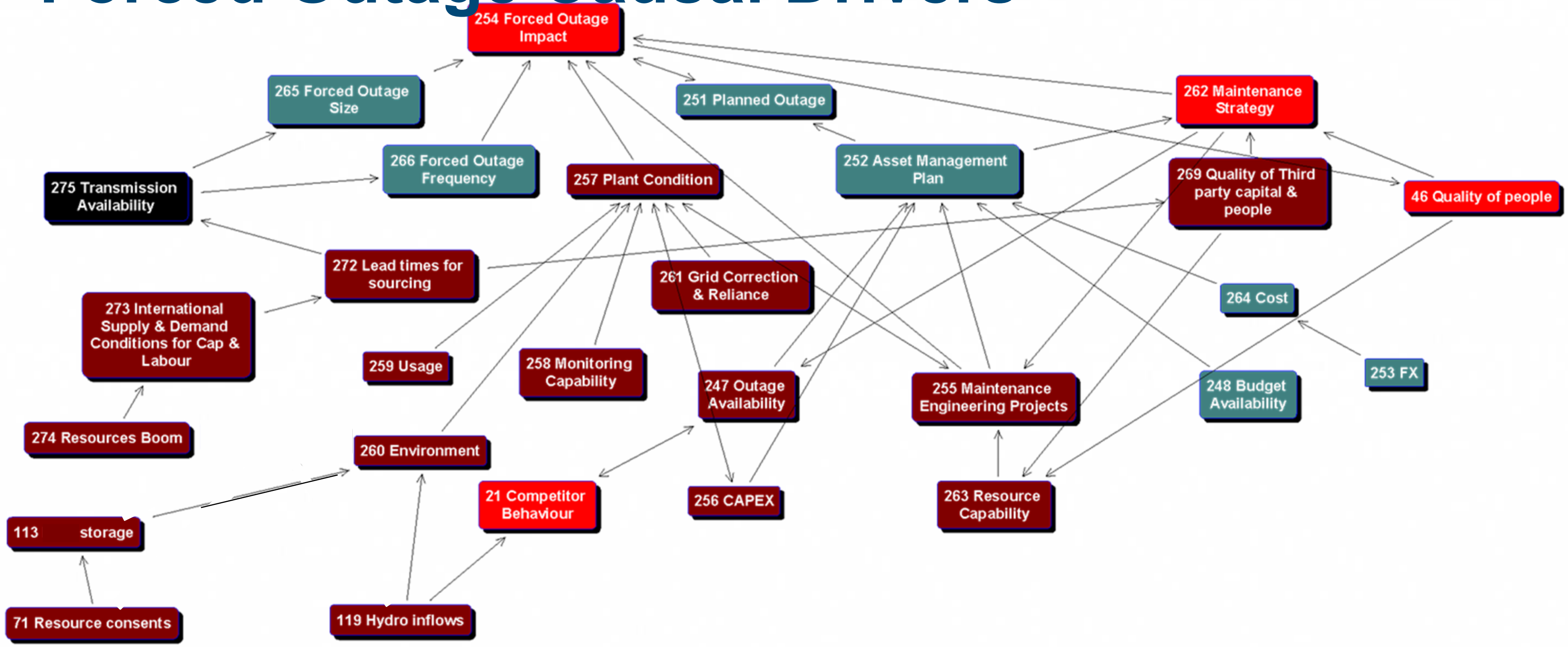
Deriving the Full Risk Profile
Forced Outage Causal Drivers



- Dominated by asset management drivers and other potent drivers
- Note multiple feedback loops: e.g. Quality of people, maintenance strategy

Technical Developments

What you see

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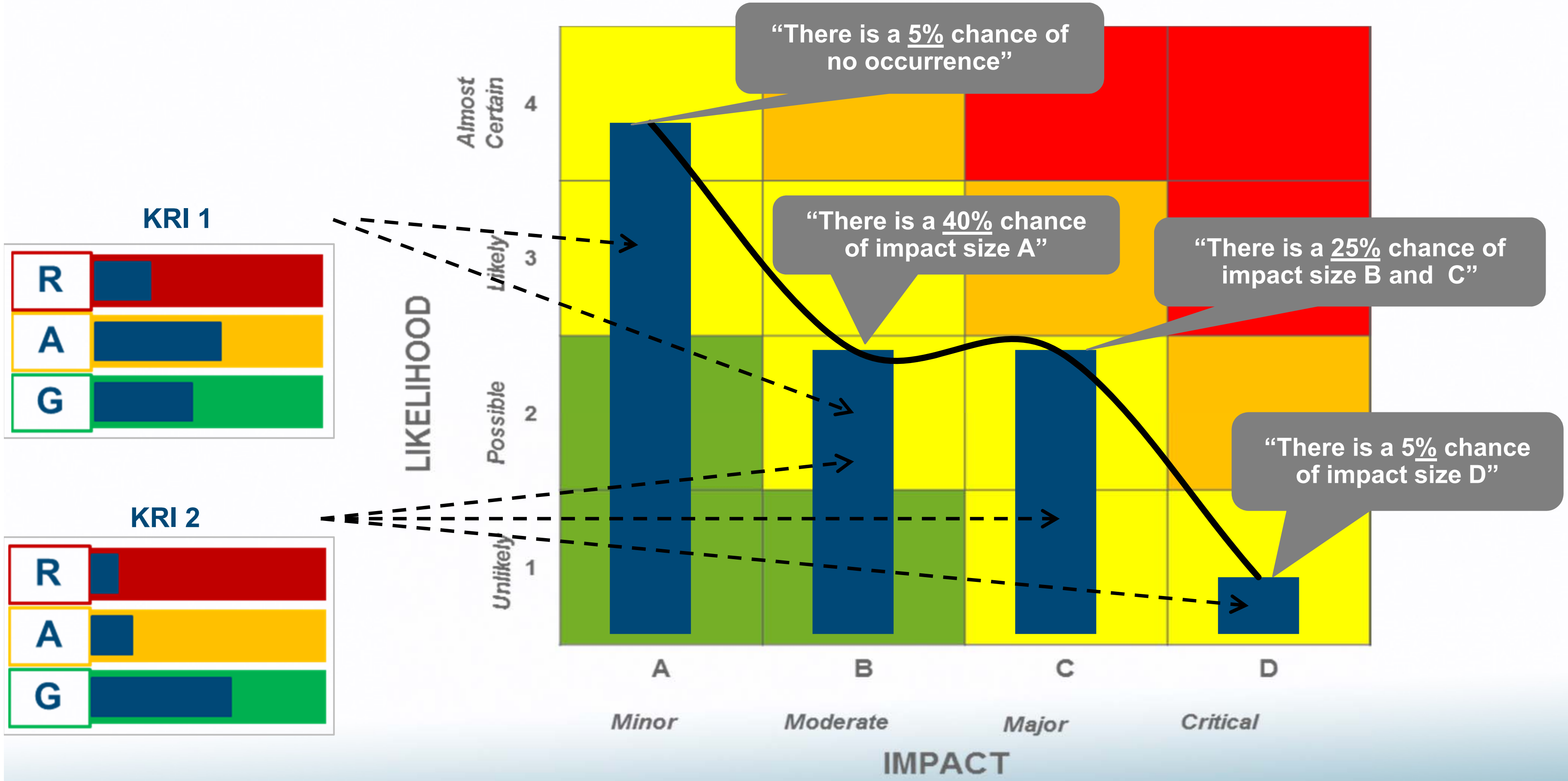
Using Data to Move Beyond Point Estimates

What do key risk indicators (KRIs) tell us about the likelihood of each type of risk outcome?



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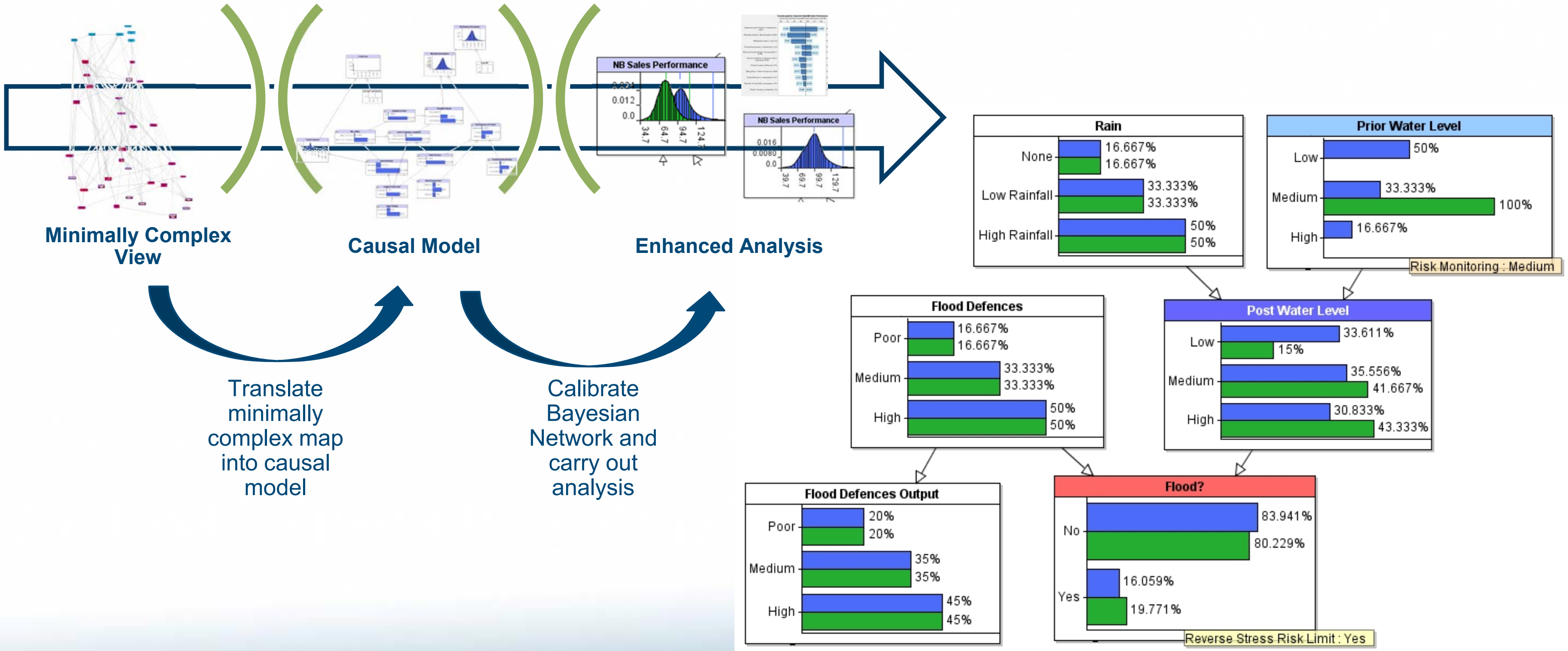
Causal Modelling with Bayesian Inference

Prediction with Explanation

Causal modelling techniques can be used to formally demonstrate how indicators flow through to the business outcomes being studied. Framework retains the dynamic links between causes and losses so risks are viewed in context and incorrect conclusions from silo-thinking are avoided.



A Bayesian Approach

- Bayesian networks are a method which can integrate dependencies directly between trigger events, risk drivers, and consequences
- Simultaneously assess all levels of outcomes (profit, capital)
- Can think of the prior as the “theory”, and the evidence as “observation”
  – All scientific fields use Bayesian statistics, so why don’t we!

$$P(A,B) = p(A/B).p(B)$$

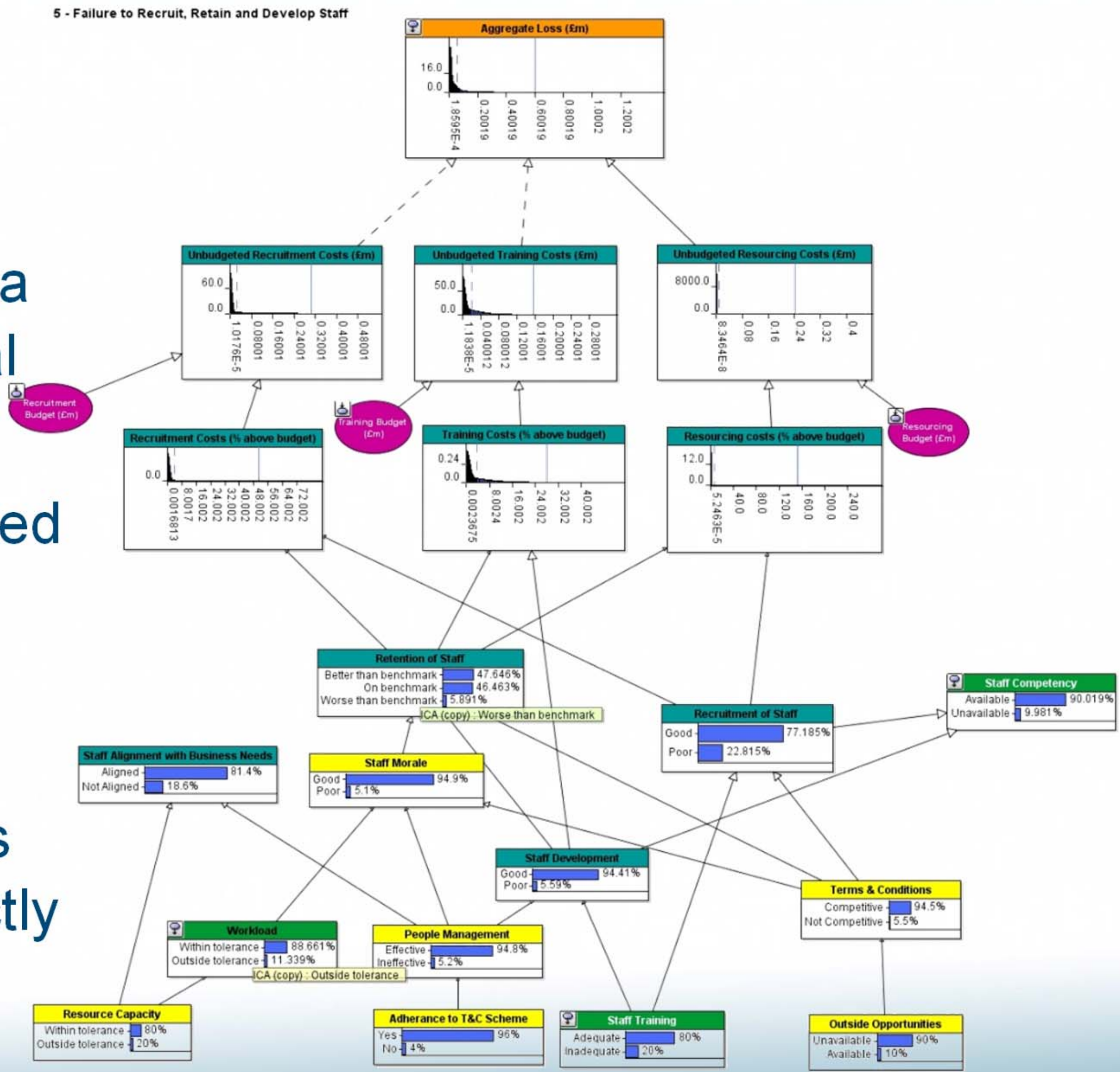
$$P(B,A) = p(B/A).p(A)$$

$$\therefore P(A/B) = \frac{p(B/A).p(A)}{p(B)}$$

where
P(A) is the prior
P(A/B) is the posterior
P(B/A)/P(B) is the evidence

What is a Causal Model?

- A causal model is one which conditions outcomes directly upon a set of interrelated causal factors
- Causal factors are defined directly in terms of business language
- It captures the complex web of interrelationships and dependencies directly from the outset



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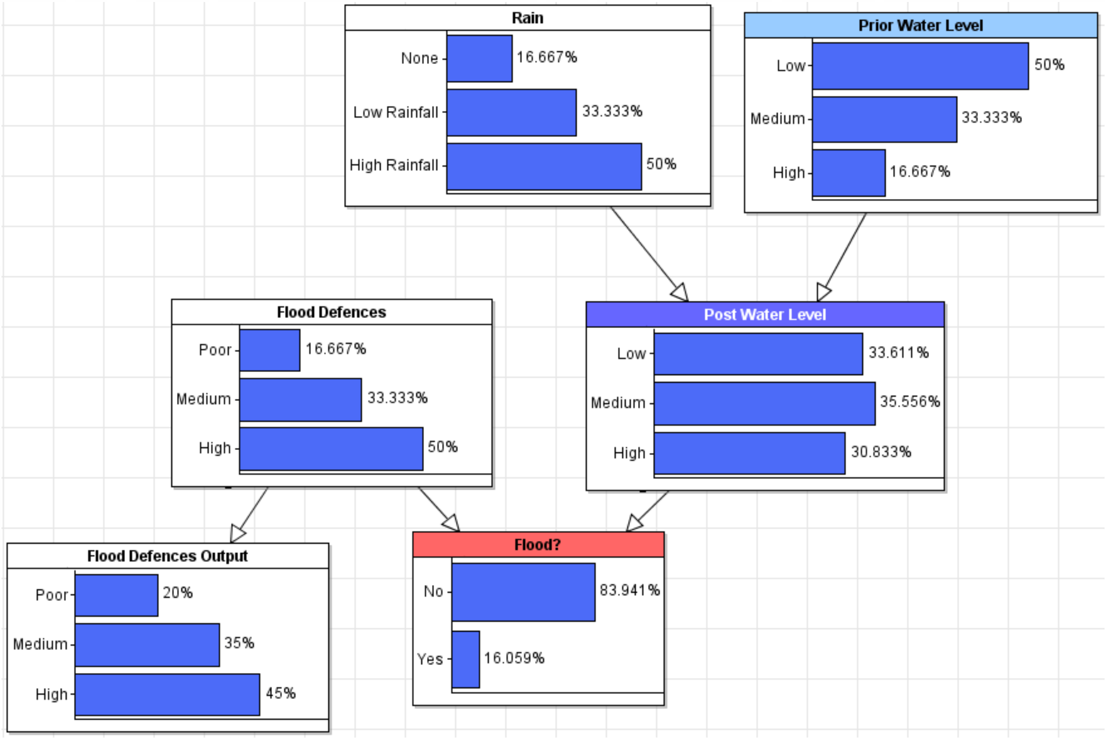
Simple BN Case Study - Flood Model

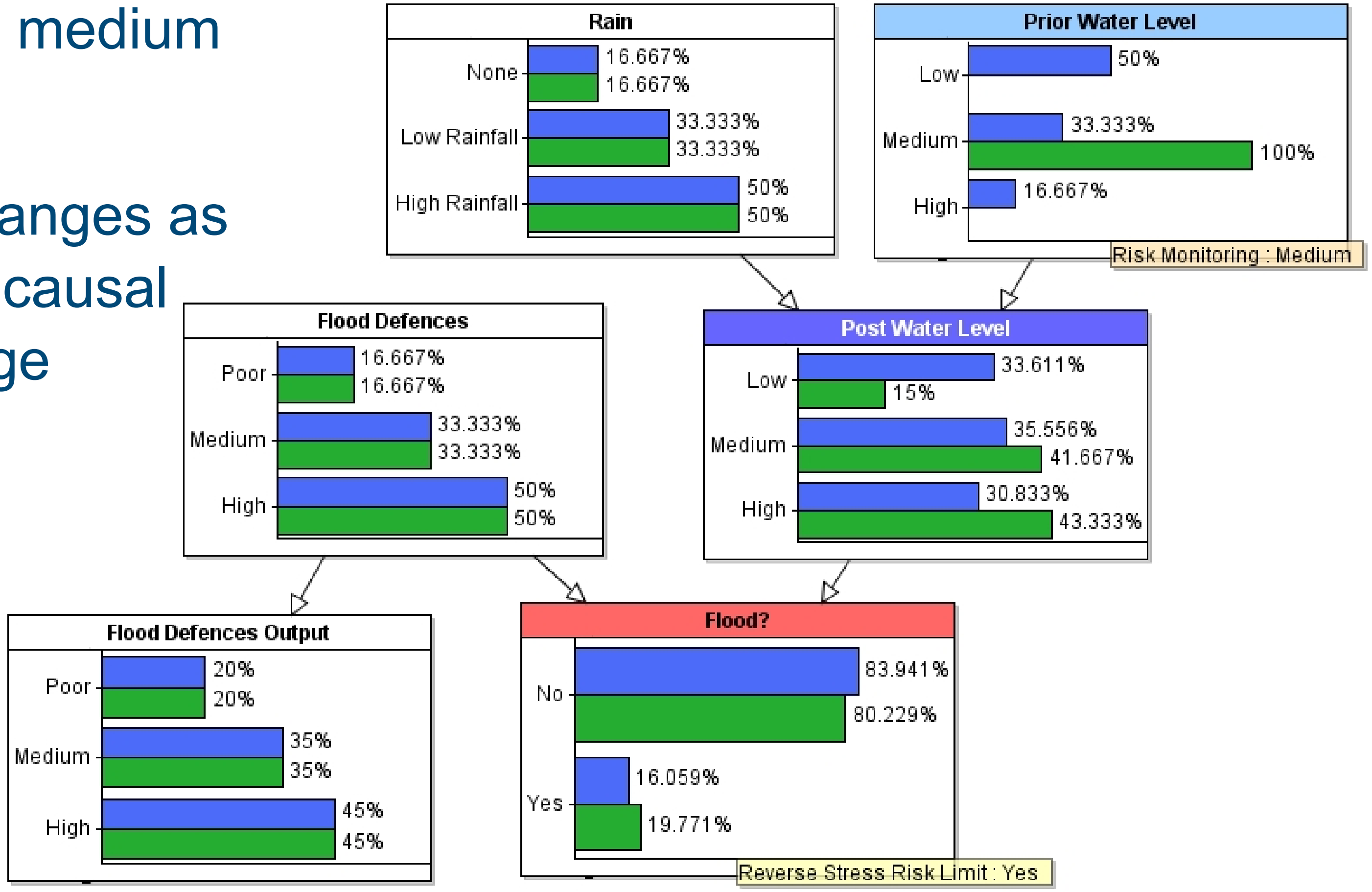
- Outcomes:
  - Prob(Flood)
- Risk indicators
  - Rain (forecast)
  - Dam levels (avg)
- Risk mitigants
  - Quality of flood defenses (measurable but uncertain)



Source: AgenaRisk

Risk Monitoring

- Prior water = medium
- Risk level changes as the states of causal drivers change



- Consistent states of other variables calculated using Bayesian inference

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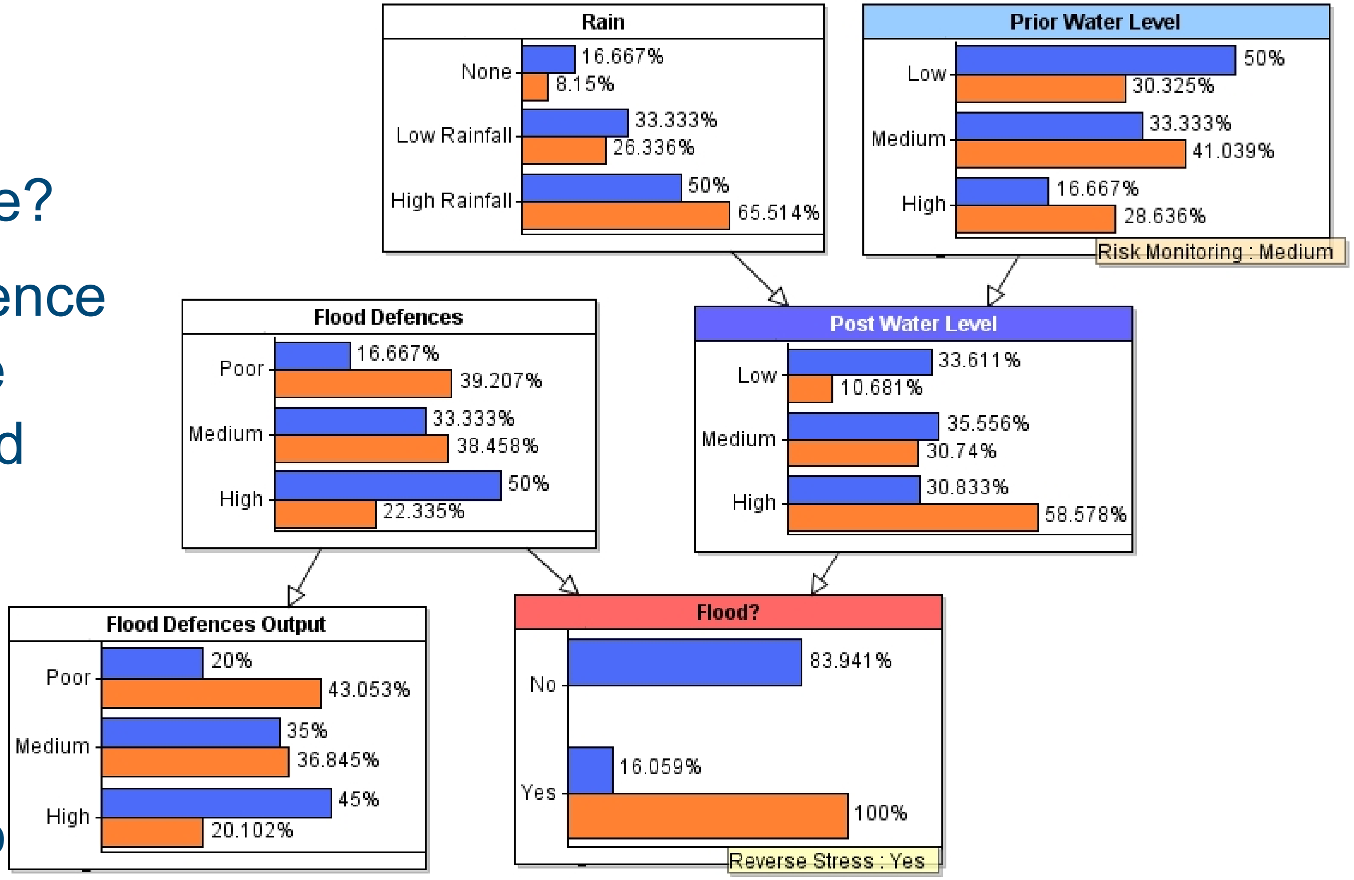
Reverse Stress Test

- Flood = 100%
- What does the system look like?
- Bayesian inference used to resolve states of related drivers
- This is how we resolve risk appetite statements into consistent risk driver limits



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Technical Developments

Relationships

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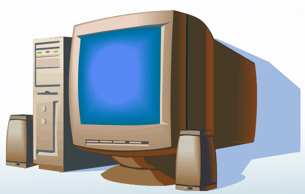
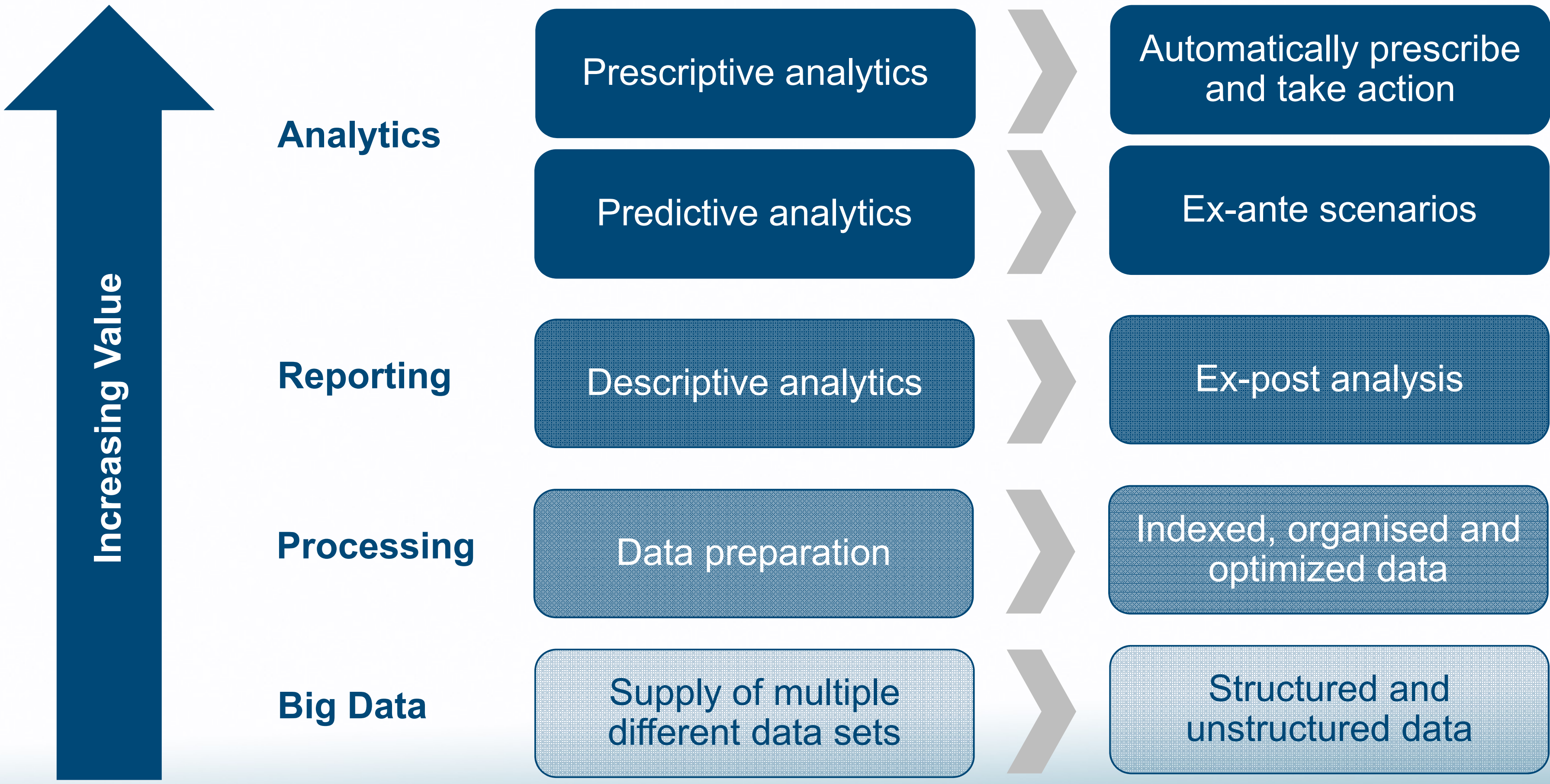
Unsupervised vs Supervised Techniques

Derivation of rules / algorithms to search data to uncover correlations and patterns	*Human judgment required to either structure the analysis or as an information source itself*
▪ Decision trees	▪ Linear multifactor regression
▪ Random forests	▪ Conditional / Bayesian probability
▪ Neural nets	▪ Non-linear copulas
▪ Nearest neighbours	▪ Cognitive mapping
▪ Support vector machines	▪ Bayesian networks
▪ Cluster modelling	▪ Phylogenetics
▪ Mutual information	▪ Network analysis



Data Analytics

Data is a key strategic asset, but only part of the solution



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Information Theory Shows us the Way

- Perhaps the most critical question in risk management:

  "Do I have any information upon which to condition an outcome / risk driver etc. and what quality level do I place on it?"

- Information theory concepts:
  - Entropy: quantifies the uncertainty involved in predicting the value of a random variable
  - Mutual information: quantifies the amount of information in common between two random variables

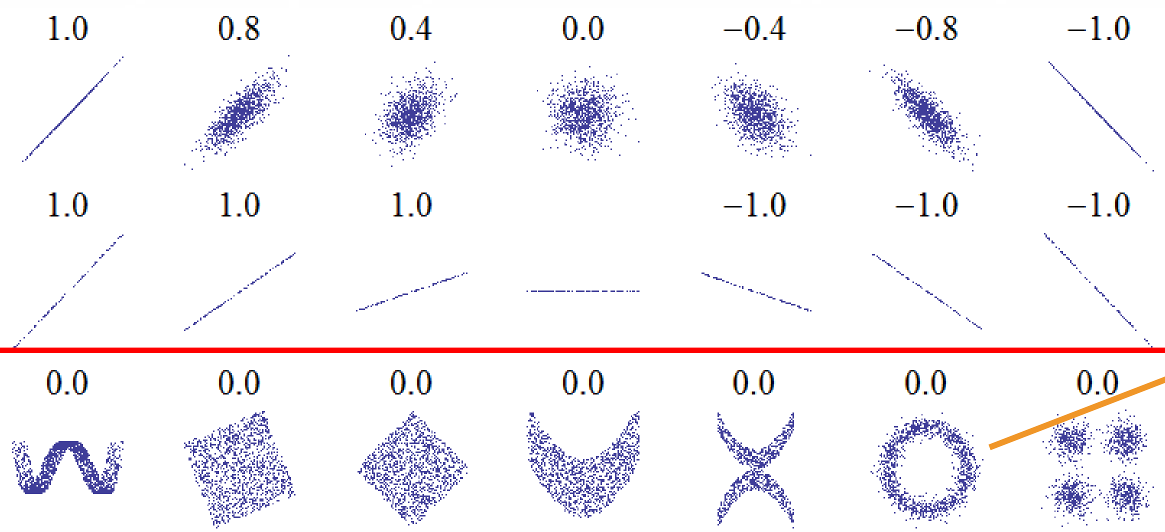
    $$I(x) = -\log p(x)$$

- In light of no other information, the principle of maximum entropy applies: all outcomes are equally likely

Connectivity – Capturing Non-Linearity

- Typical correlation measures cannot spot non-linear dependency
- Mutual information sharing can

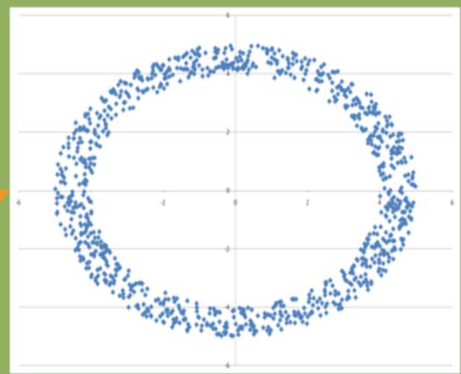
Different levels of correlation



<u>Example</u>

$\Theta \sim U[0,2\pi]$
$R \sim U[4, 5]$
$X = R \cos \Theta$
$Y = R \sin \Theta$

Sample of 1000



Correlation = 0.0
Mutual Info = 1.0

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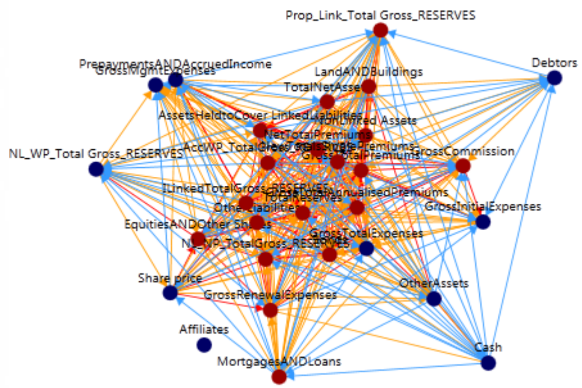
Assessing Network Connectivity & Complexity

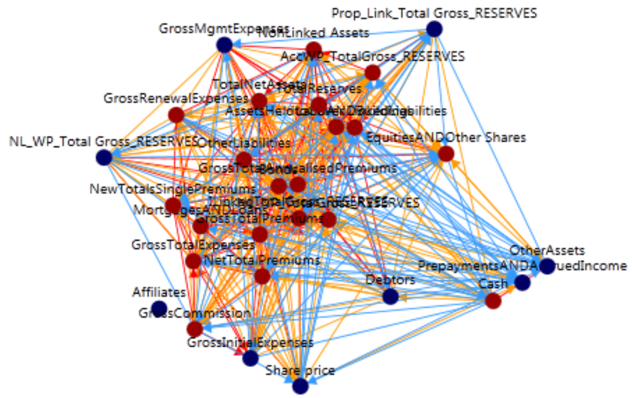
Non-linear measures of dependence are critical

2003

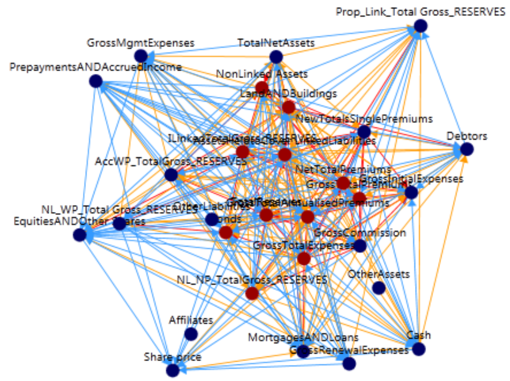


2004

Peak of complexity



2005



- Complexity changes significantly over the year, with several of the key drivers changing between 2003 to 2005

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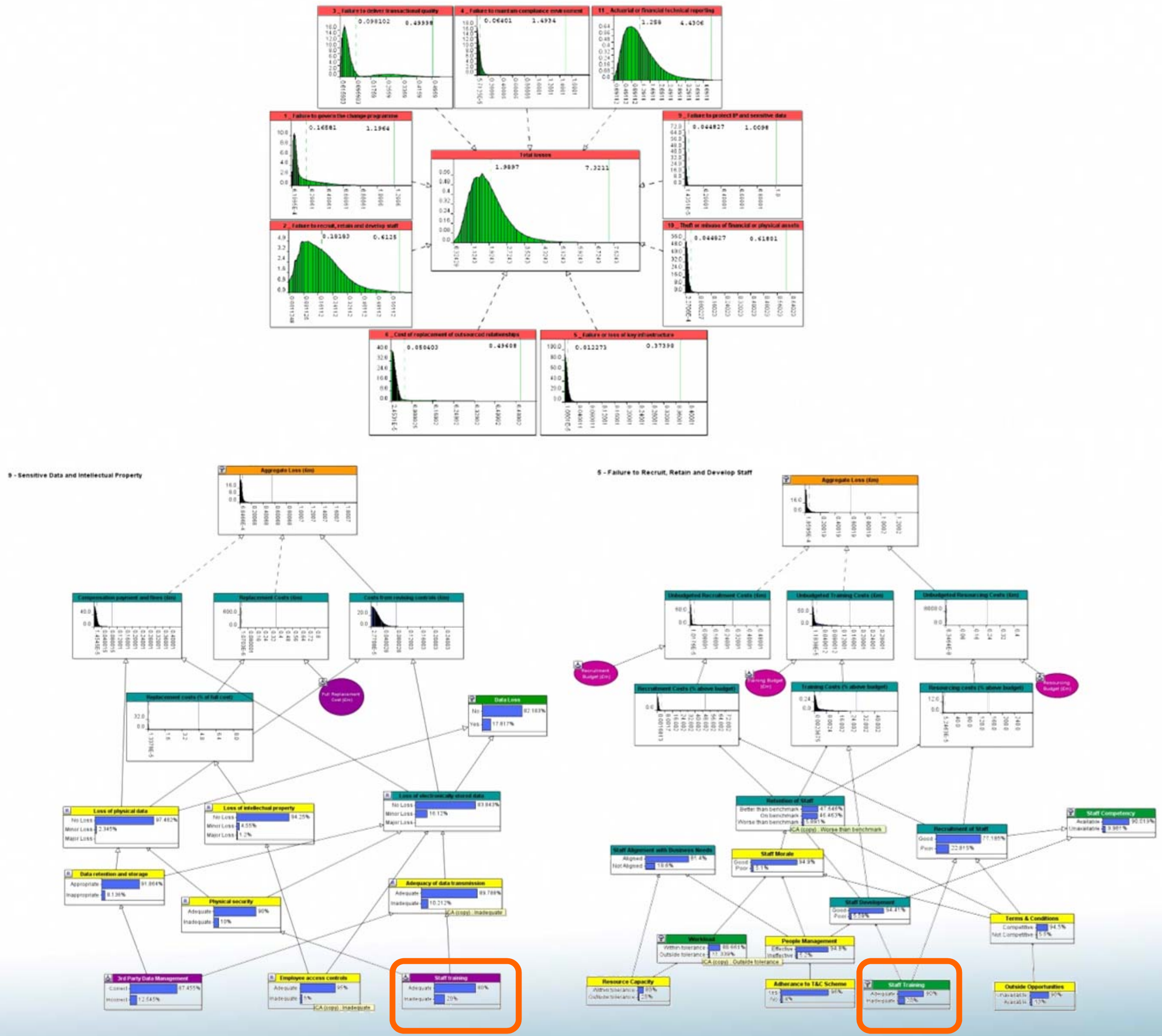
Aggregate Loss – Dependency Structure

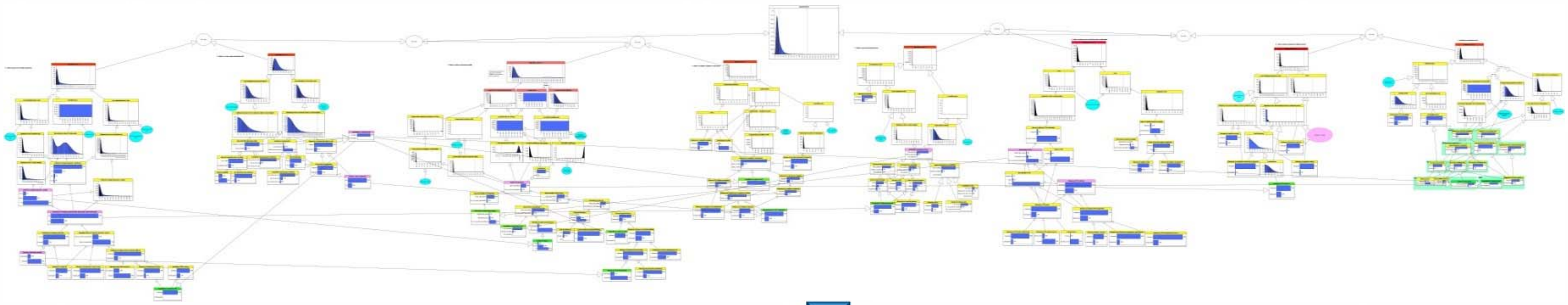
- A profoundly different way of aggregating risks
- Diversification at all parts of the loss distribution can now be explained by the states and interrelationships of business drivers
- No need for abstract correlations, copulas



Correlation from Cause

Validating Dependency Structures

- Correlations measure a degree of co-variation. You can determine this co-variation for complex phenomena by using causal models of their dynamic relationships.
- The models more naturally allow for an understanding of regime shifts in behaviours and allow you to meaningfully stress dependency parameters used in other models.



$$\rho = \begin{pmatrix} 1 & 0 & 0.023035 & 0 & 0.0043 & 0 & 0 & 0.000013 \\ 0 & 1 & -0.000001 & 0.00048 & 0 & 0 & 0 & 0 \\ 0.023035 & -0.000001 & 1 & 0 & 0.011645 & 0.044774 & 0.00211 & 0.000397 \\ 0 & 0.00048 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0.0043 & 0 & 0.011645 & 0 & 1 & 0 & 0 & 0.000007 \\ 0 & 0 & 0.044774 & 0 & 0 & 1 & 0.004908 & 0.000026 \\ 0 & 0 & 0.00211 & 0 & 0 & 0.004908 & 1 & 0.000001 \\ 0.000013 & 0 & 0.000397 & 0 & 0.000007 & 0.000026 & 0.000001 & 1 \end{pmatrix}$$

Applications

Operational Risk

Section 3a

Milliman Research Report 2013

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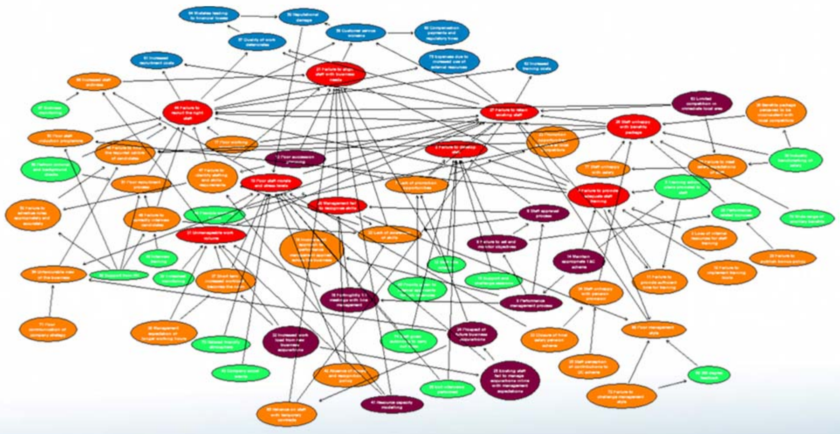
Risk - Failure to recruit, retain and develop staff

Cognitive Map Analysis

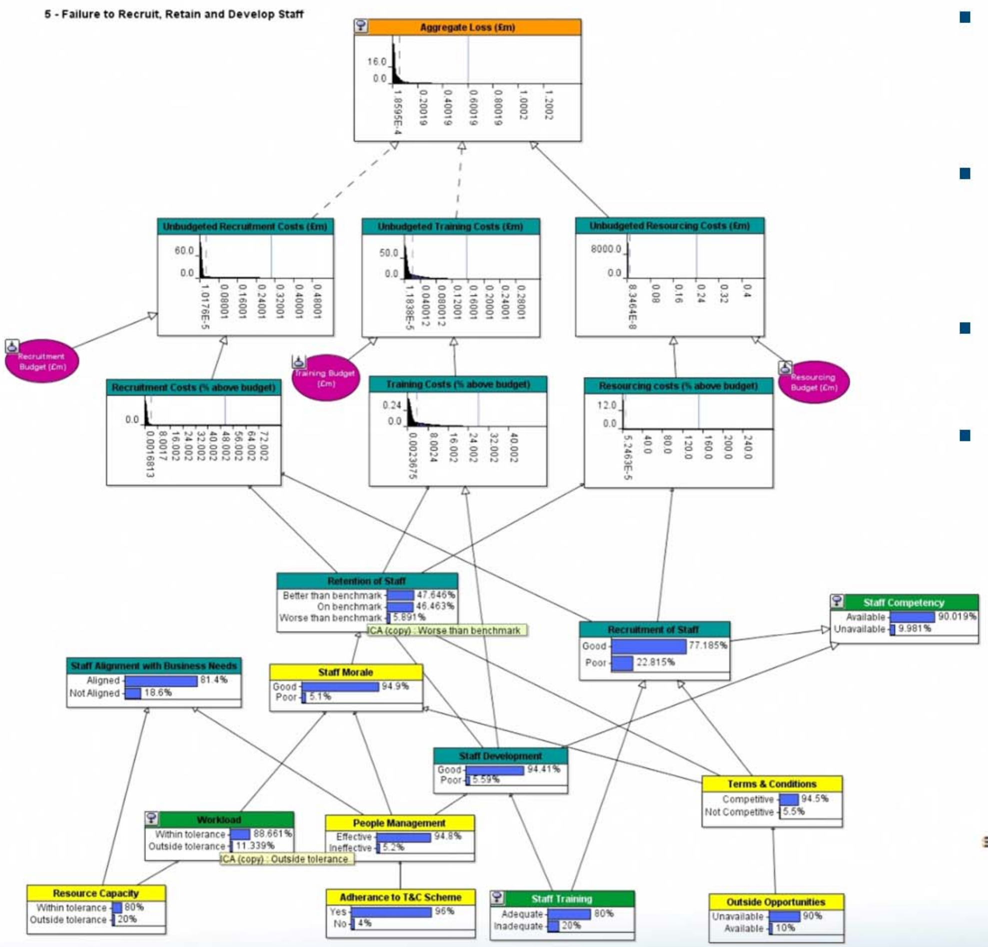
- Key concepts:
  - *Impacts*: customer service worsens, quality of work deteriorates
  - *Drivers*: failure to provide adequate staff training, unmanageable work volume, failure to align staff with business needs
  - *Controls*: staff appraisal process, performance management process
- Map properties



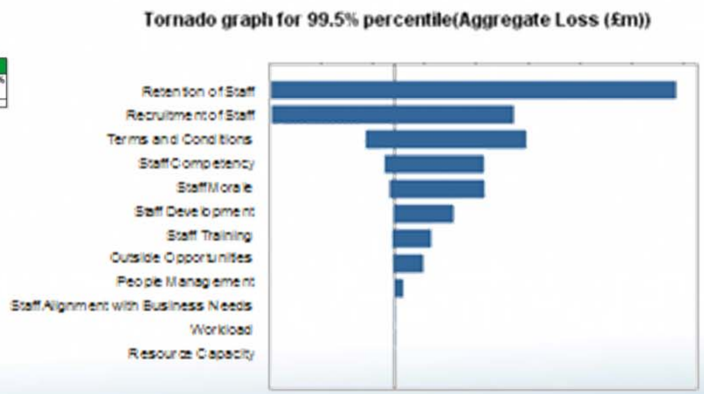
Property	Check
Links: Nodes ≥ 2 : 1	✓
Hyperconnectivity	✗
Heads (% of Nodes)	3%
"Heads" all impacts?	✓
"Tails" (% of Nodes)	21%
Free nodes?	✗
Loops?	✓

Risk - Failure to recruit, retain and develop staff

Risk Quantification using a Bayesian Network



- Aggregate Loss:
  - ***Mean***: Xm
  - ***99.5%***: Ym
- Sources of loss: **Unbudgeted recruitment, training and resourcing costs**
- Business inputs**: Resourcing , Training and Recruitment budgets**
- Sensitivity Analysis:



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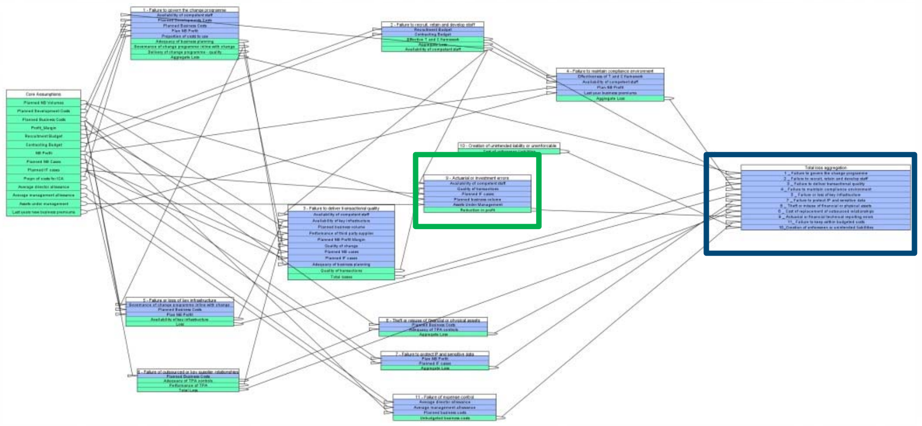
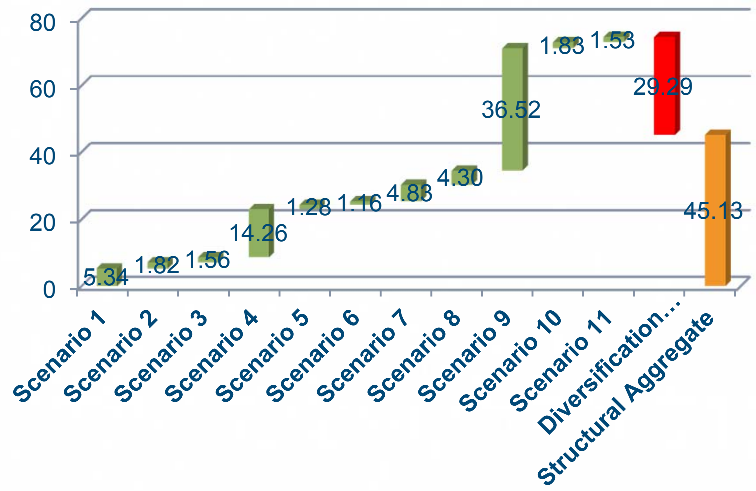
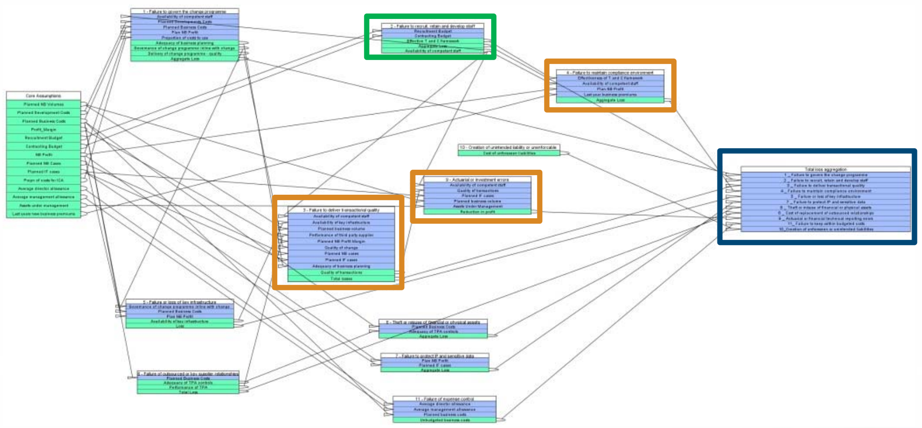
Operational Risk Capital

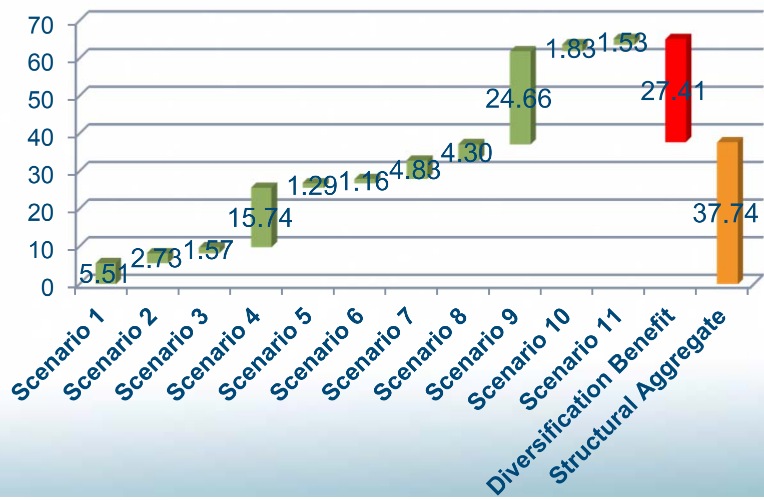
Unique





Common





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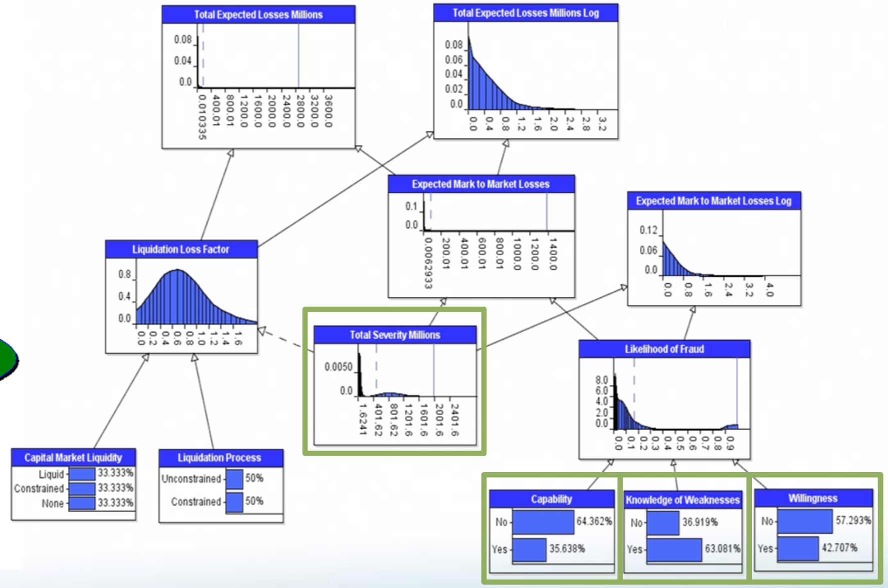
Assessing Extreme Risk Events

Rogue Trader Scenario



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Applications

Risk Appetite

Section 3b

The Actuarial Profession

A review of the use of complex systems applied to risk appetite and emerging risks in ERM practice

BY N. ALLAN, N. CANTLE, P. GODFREY AND Y. YIN

Presented to The Institute and Faculty of Actuaries

28 November 2011 (London)

Peter Clark award for best paper in 2012 in UK Profession

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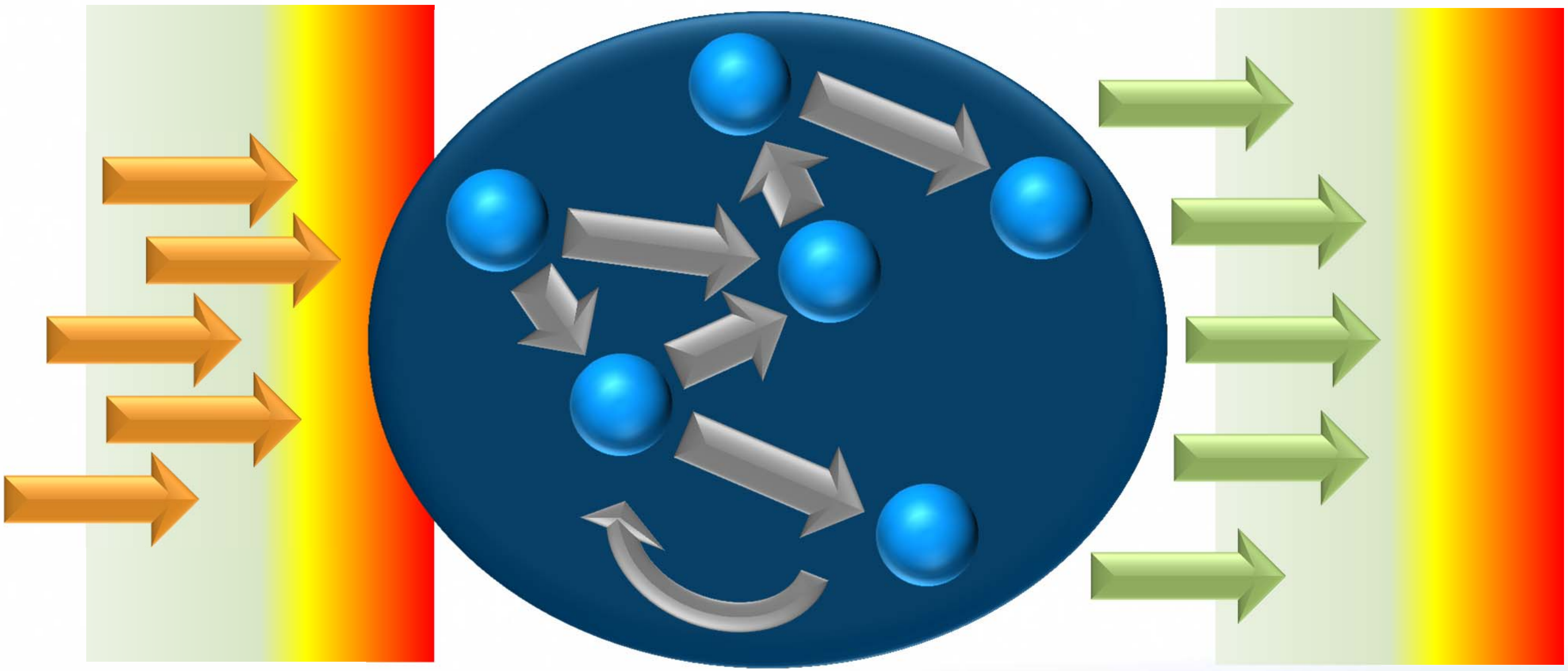
Primary Risk Appetite Challenge:

Aggregating / cascading RAS thresholds ←→ risk limits

Knowing how these ***...interact...*** ***...to produce these***



It is essentially a large, complex multi-objective optimisation and control challenge

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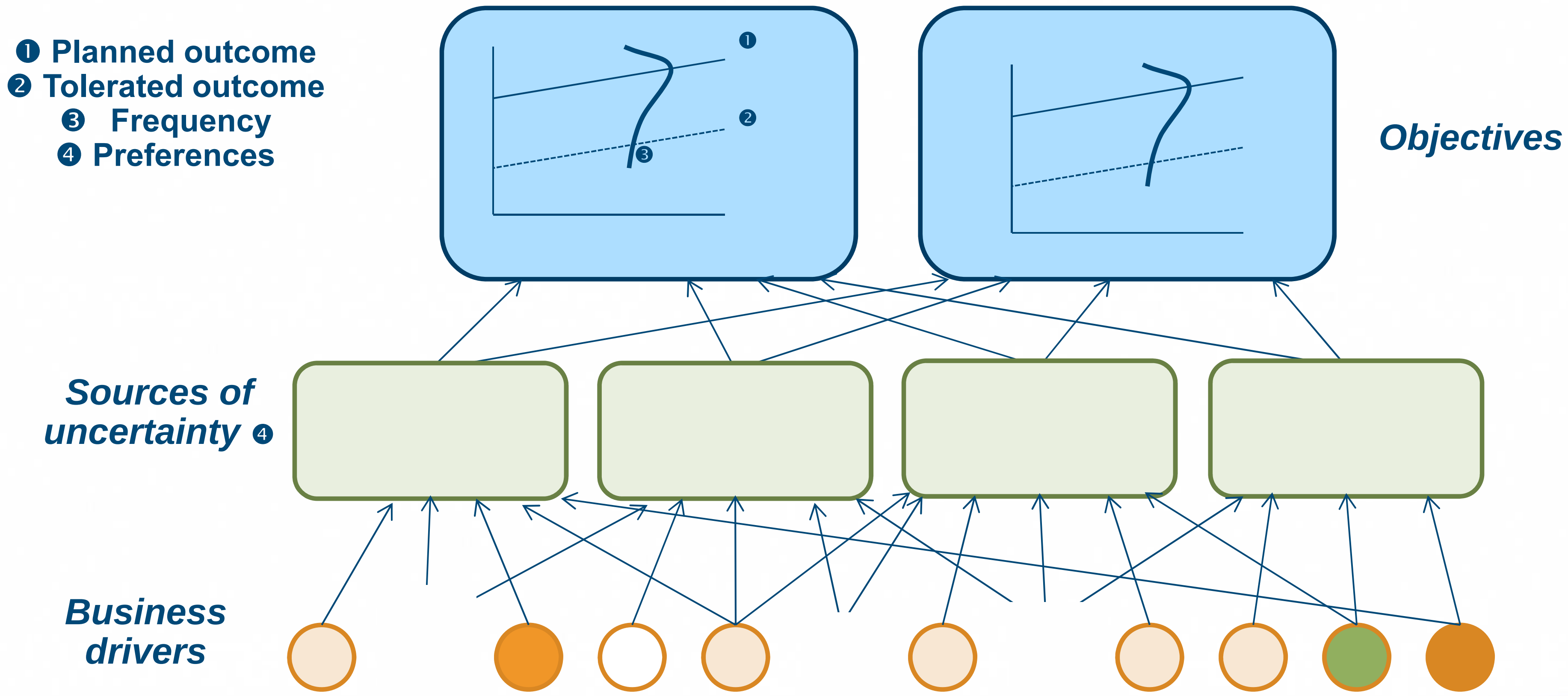
Risk Appetite Components



Adaptation and emergence make this "hard"

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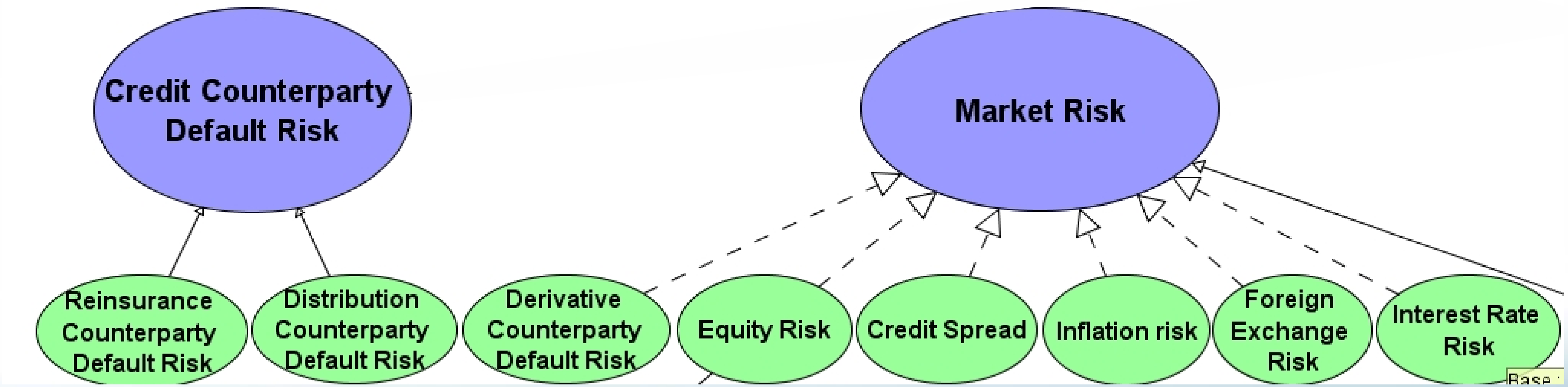
Business Objectives Linked to Risk Sources

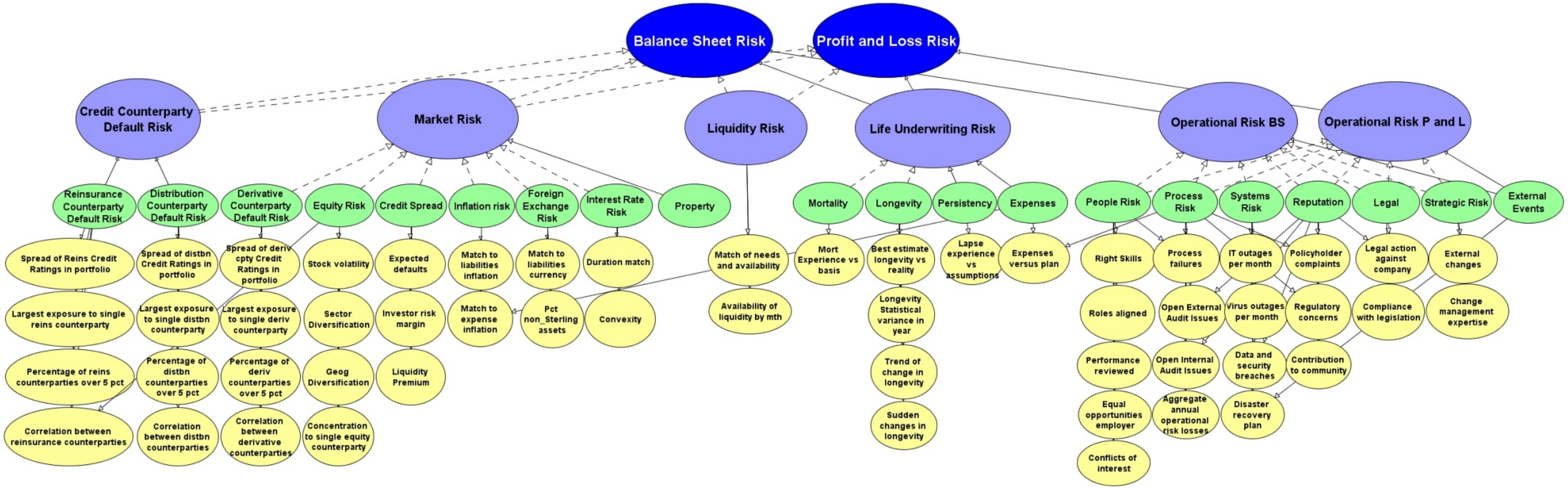
- Risk Sources:
  - Market
  - Credit Counterparty Default
  - Liquidity
  - Underwriting
  - Operational
- Contribution of risk source to overall risk set from:
  - Capital analysis
  - Profit analysis
  - Expert judgment

Identify Sources of Uncertainty for Each Risk

- Credit:
  - Reinsurance counterparty
  - Distribution counterparty
  - Derivative counterparty (or classified under market)
- Market:
  - Equity
  - Credit spreads
  - Inflation
  - Foreign exchange
  - Interest rate



Model now links business objectives to sources of risk and indicators



- Capture multiple influences: operational risk in particular links to more than one risk characteristic

Setting Risk Appetite

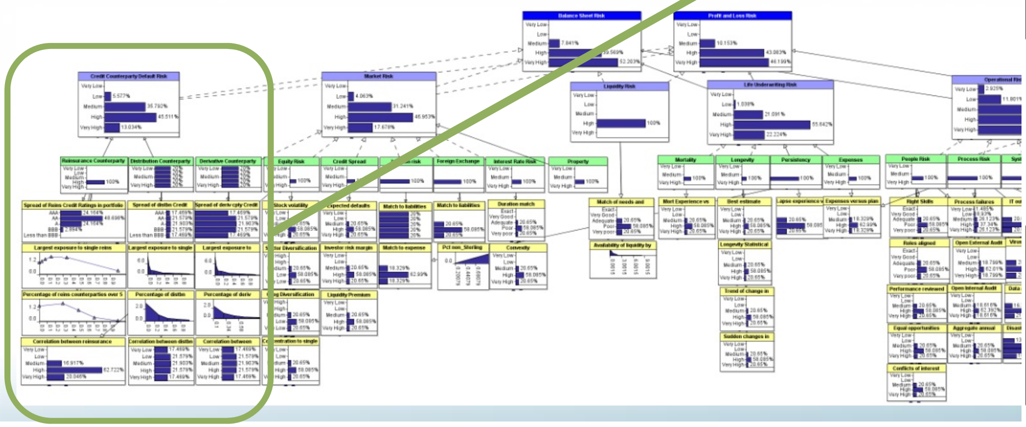
- Use propagation properties of Bayesian Networks

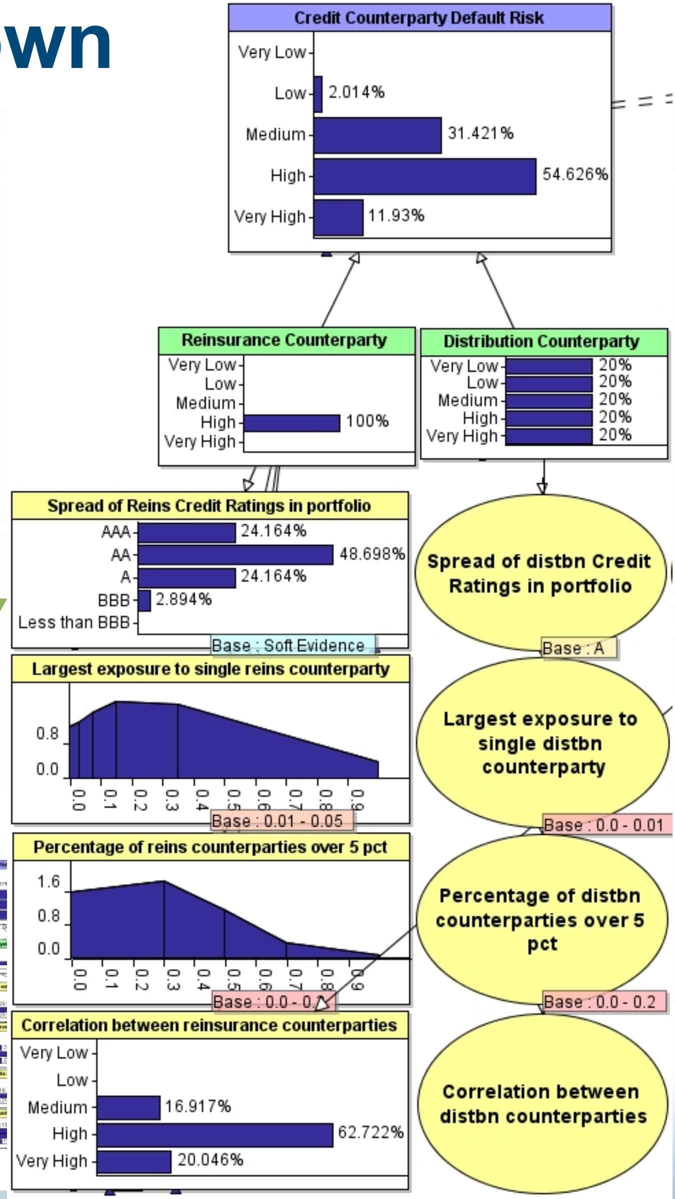
Setting an outcome here…

…tells us what the states ought to be here

Propagating Evidence Down

- Setting desired appetite levels at the top, translates into information about underlying limits e.g. counterparty credit





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Monitoring Risk Levels Against Appetite

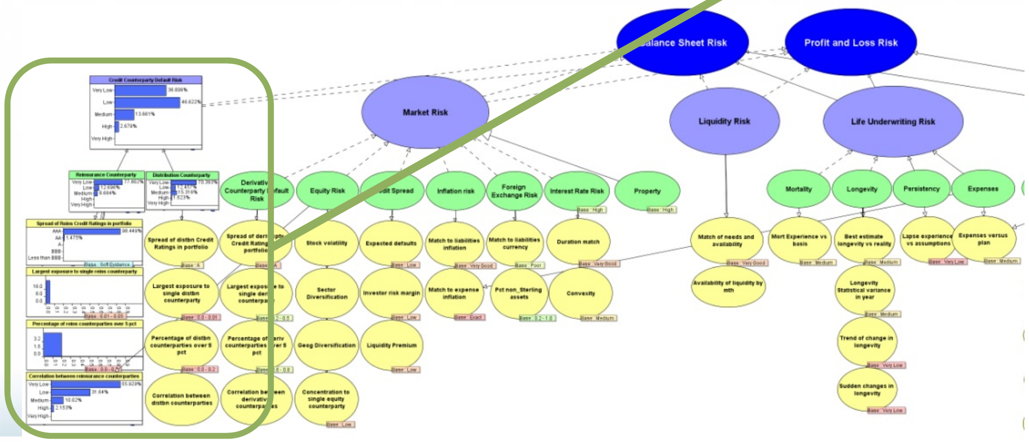
- Use propagation properties of Bayesian Networks

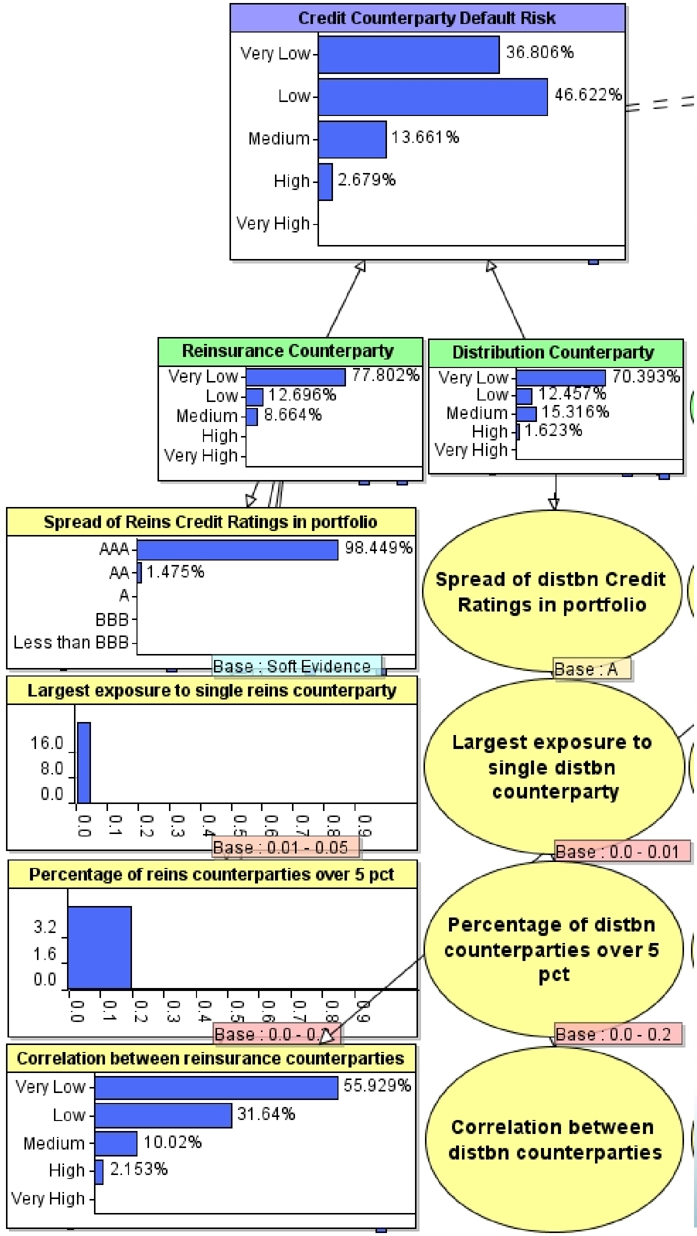
…gives us an estimate of risk levels here

Entering observed values here…

Propagating Evidence Up

- Entering actual observed indicator values gives information about risk levels versus appetite





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Applications

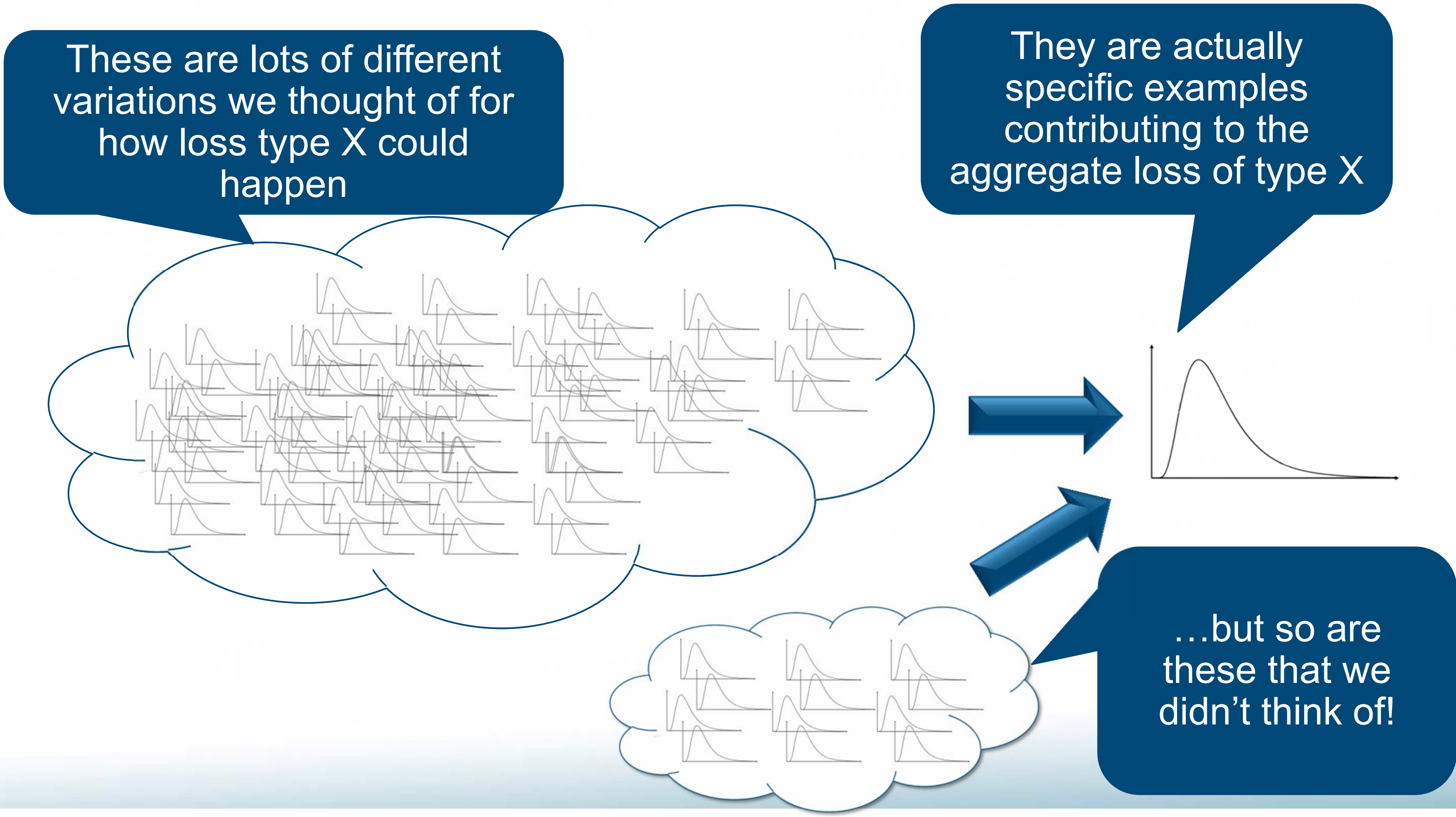
Stress Testing

Section 3c

Award for "Practical Risk Management Applications" at ERM Symposium 2013

Stress / Scenario Testing:

Overload But Incomplete



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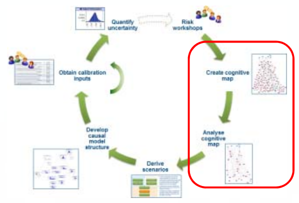
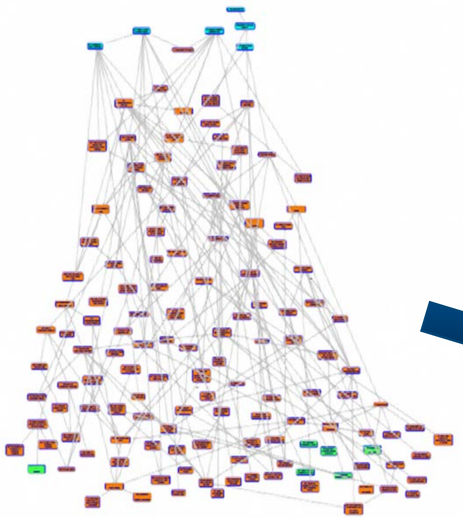
Codifying Business Intelligence

Cognitive Mapping & Analysis

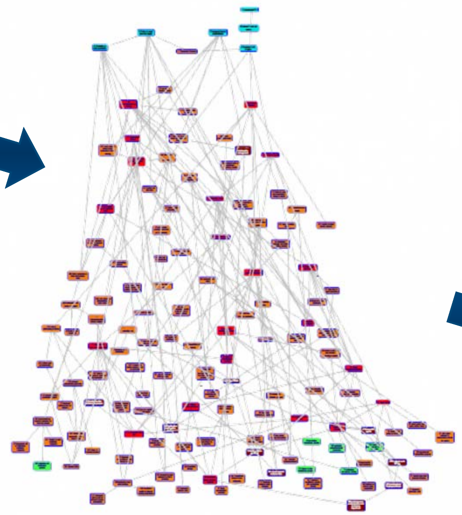




1. Detailed notes from each workshop used to translate the risk discussion into cognitive maps

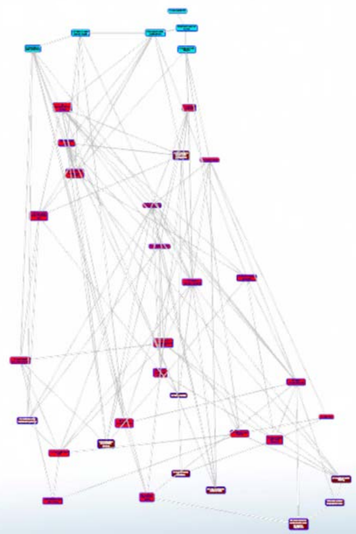
- separate cognitive maps merged together to give complete description of risk profile

2. Connectivity analysis identifies key features of risk system



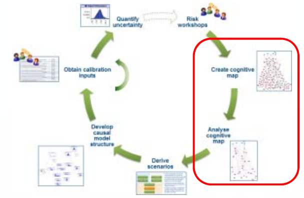
3. Collapsed view provides a ‘minimally complex’ description of the system

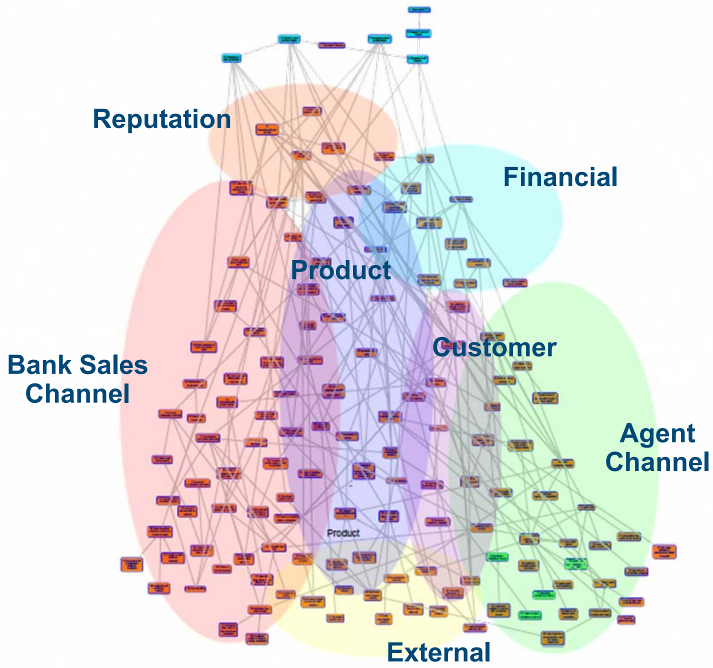
- Retains the key features necessary to understanding drivers of uncertainty



Identifying Critical Drivers

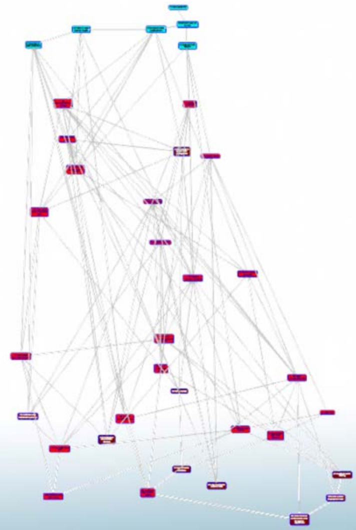
Highly connected drivers across the various silos





- Structure of the map broadly reflects the key areas discussed within the workshops
  - Financial, Agent Channel, Product, Customer, Reputation, External, Bank Sales Channel
- Visually represents the distinct risk profile of each sales channel

Cognitive analysis identified key interactions between the risk profiles



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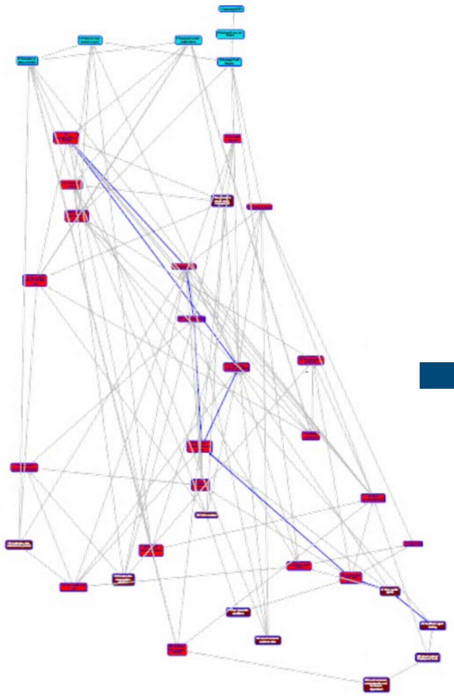
Qualitative Scenario Creation

Understand full narrative of causes to consequences



"The life company does not deliver effective agent training with respect to current regulation, industry best practice, and product knowledge. This leads to a gradual decline in the ability of sales agents to offer compliant advice and meet required sales standards.

Out-of-date and incomplete sales advice leads to increased incidence of product mis-selling across the business's product offering.

A build up of customer complaints is picked up by industry press and the regulator decides to review current sales practise."

1. Minimally complex view of the system studied to identify interesting pathways between concepts

2. Pathways used as a framework for the scenarios, with additional context included from the full cognitive map

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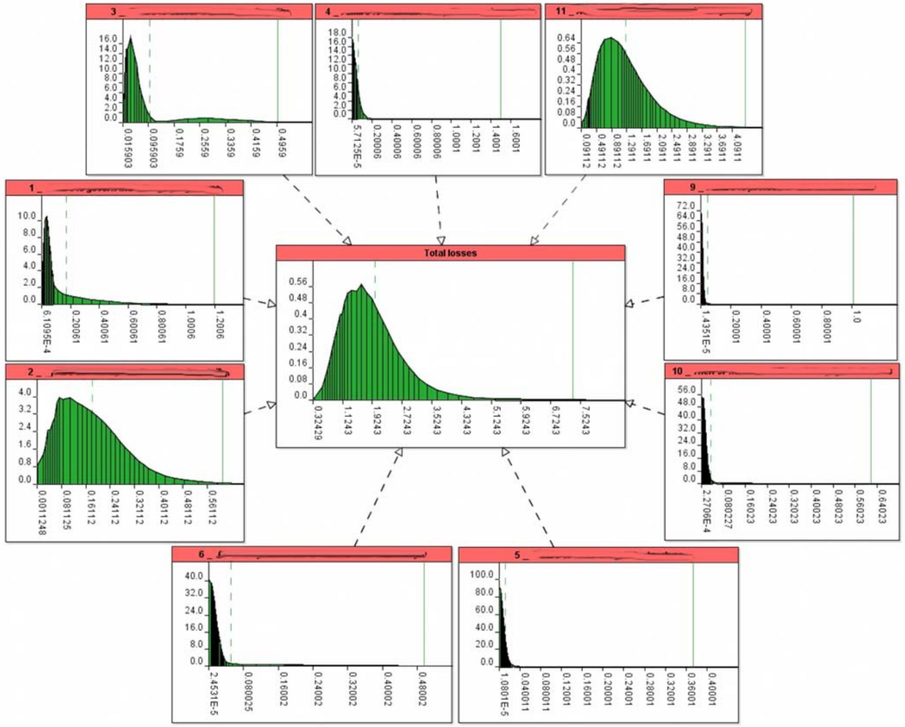
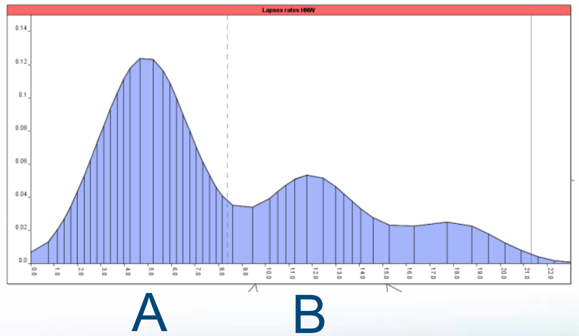
All Shapes And Sizes

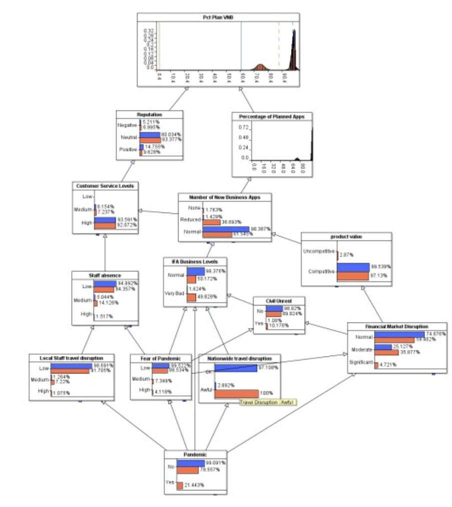


The transition from A to B will be sudden not smooth

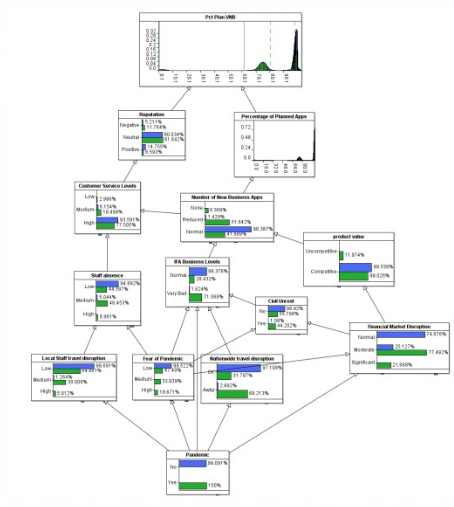


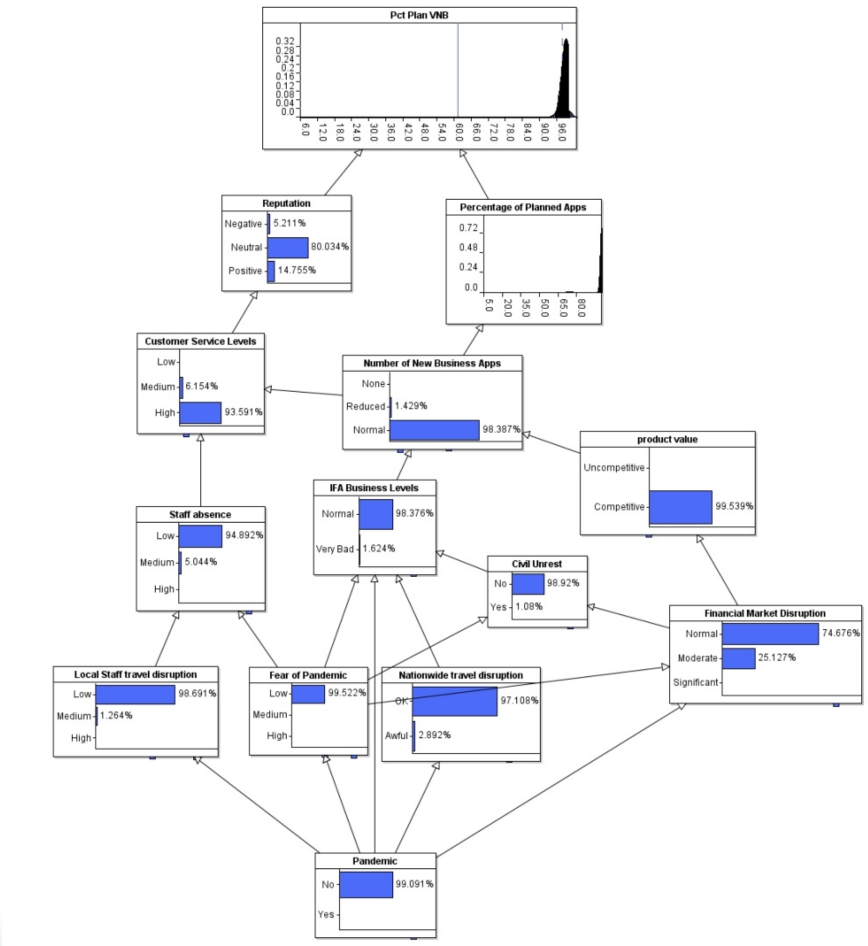
Recovering Scenarios

Travel Disruption

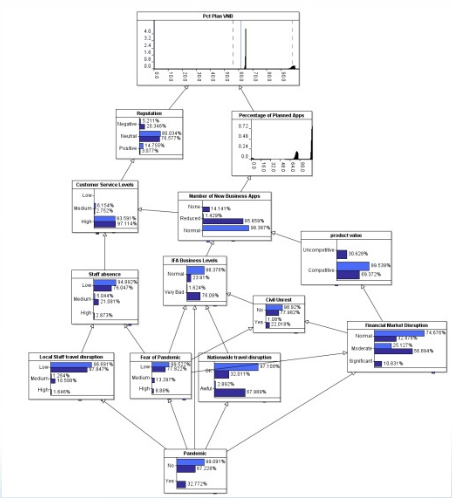


Pandemic

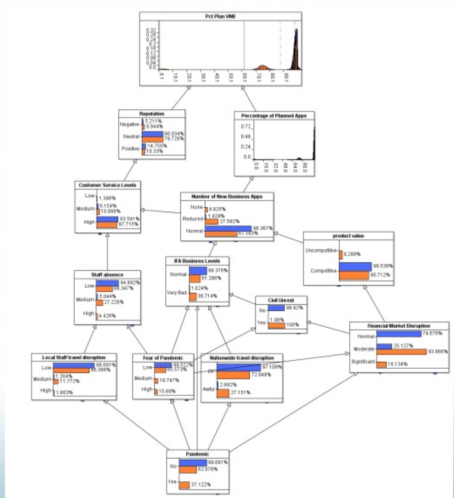




Reverse Stress



Civil Unrest

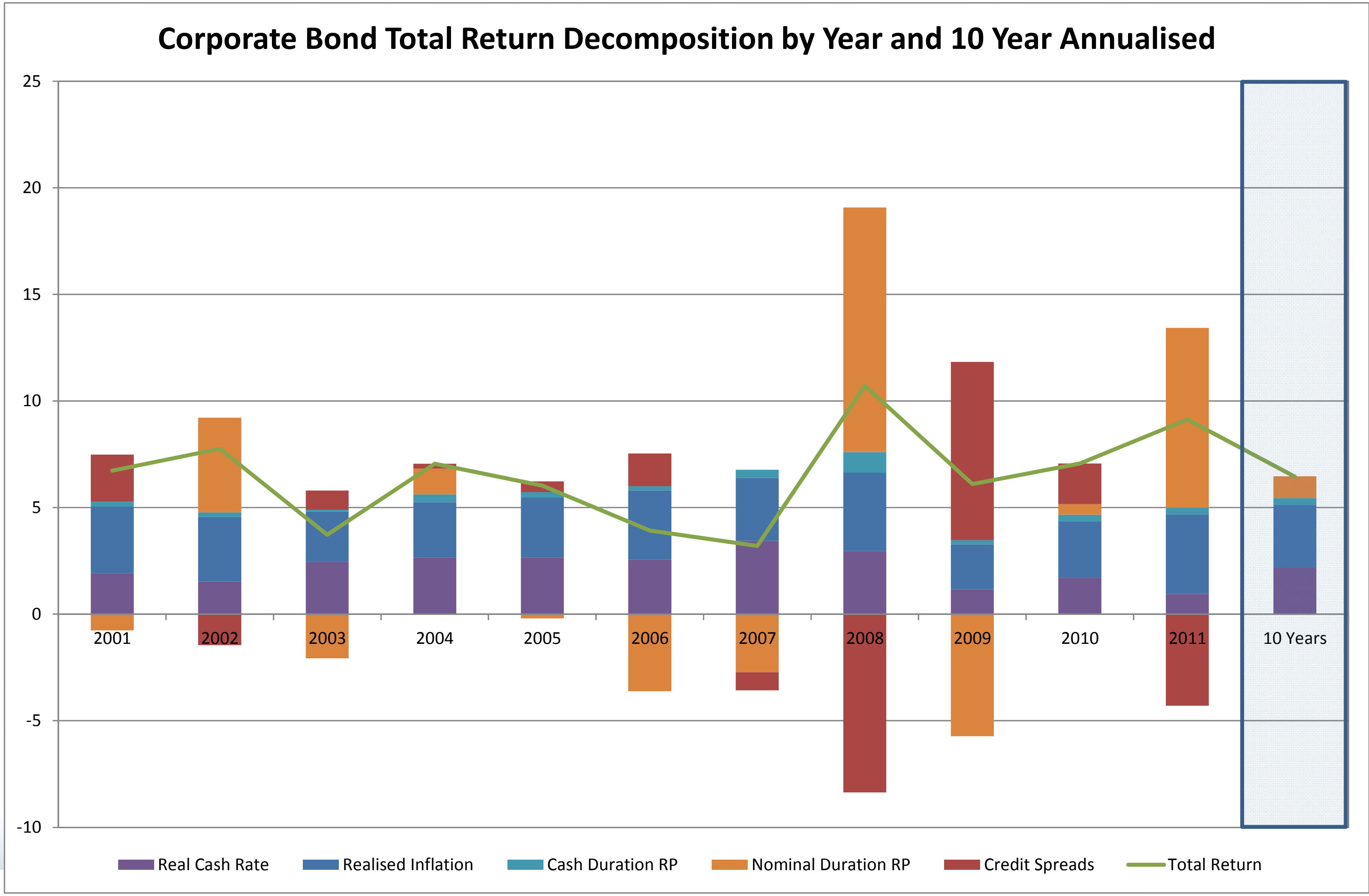


Applications

Interest Rate Risk

Section 3d

Causal Factor Explanation of Corporate Bonds



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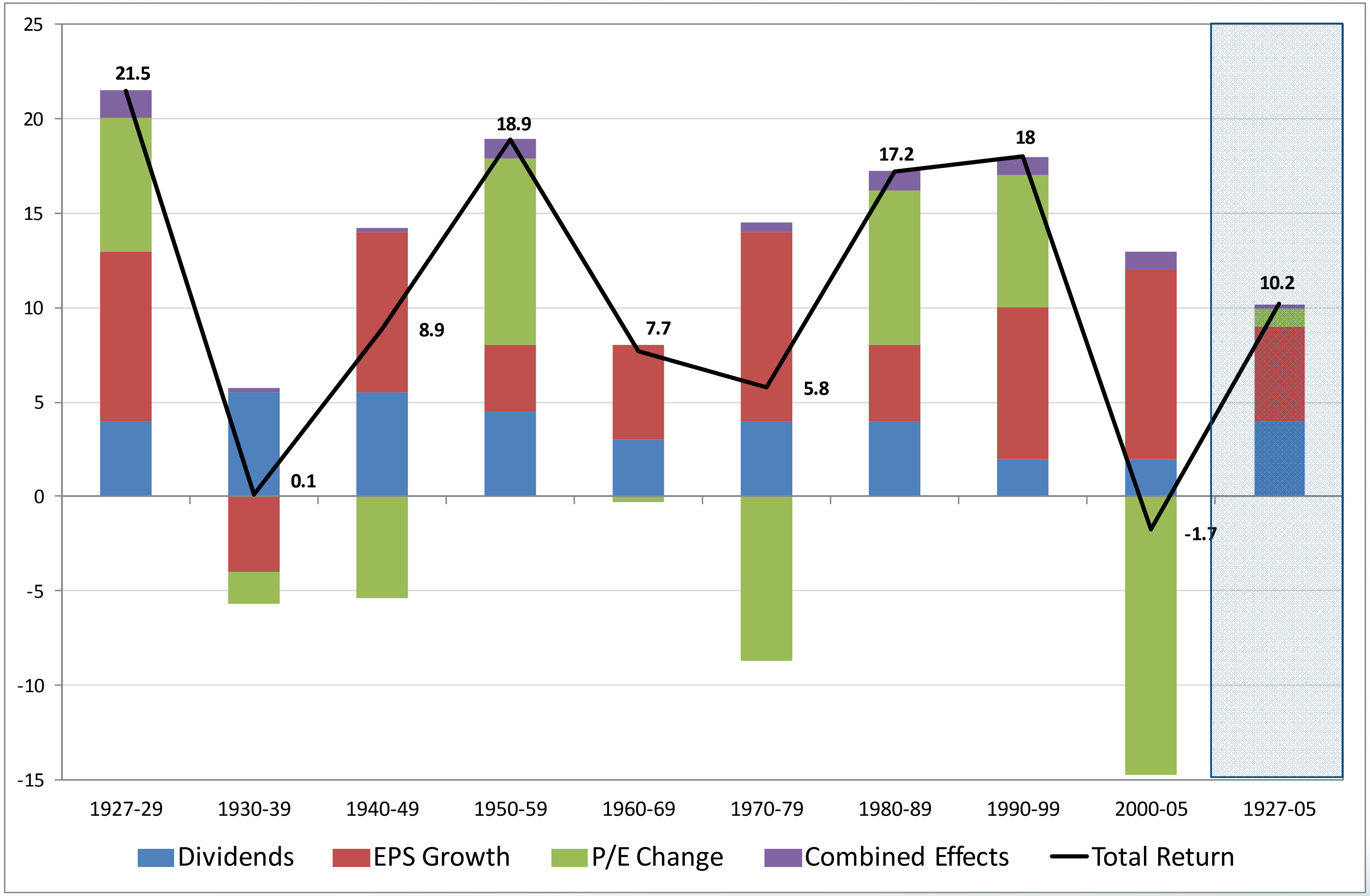
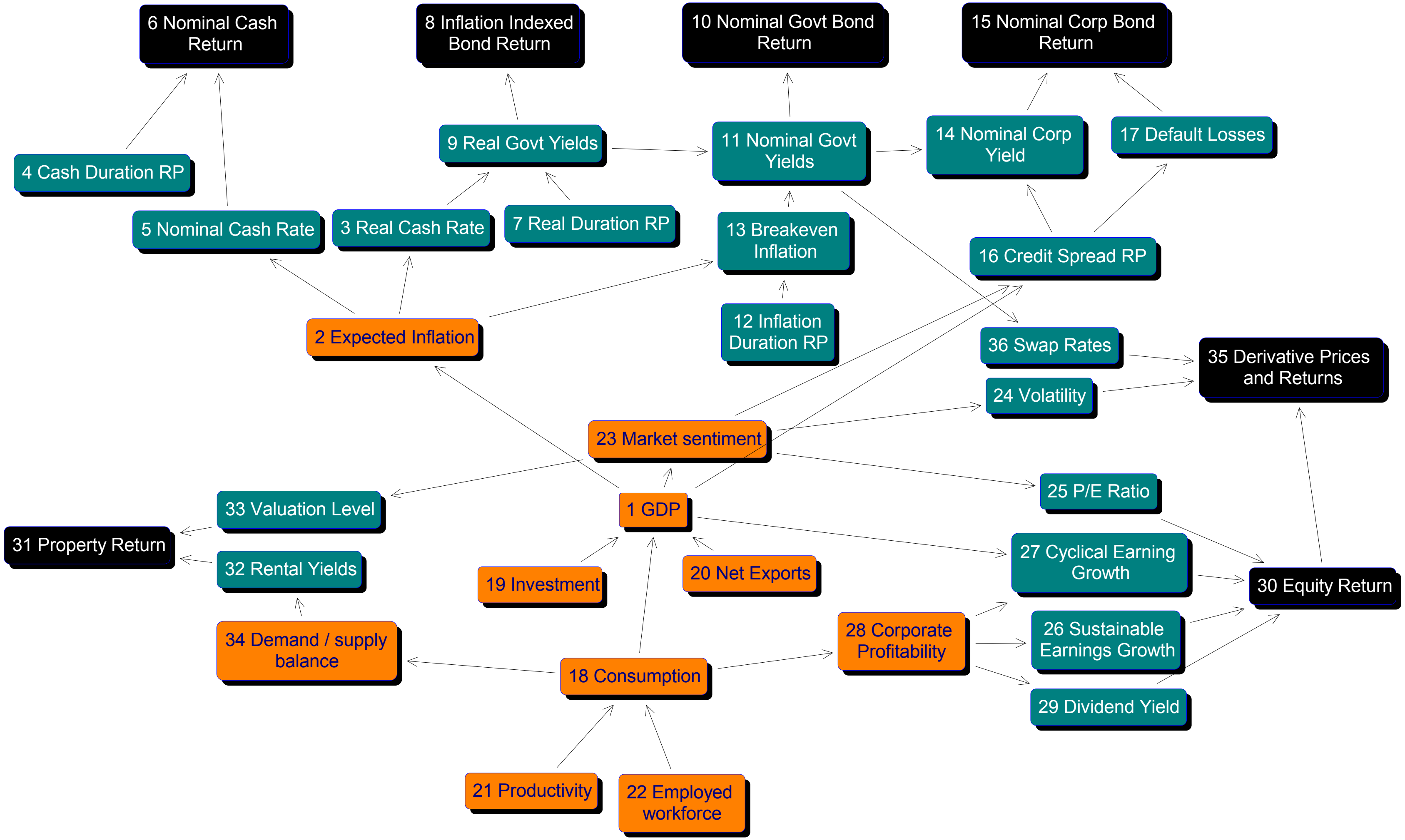
Long Term US S&P Return Decomposition



Source: Priest et al (2007)

Eliciting the Causal System Structure to Understand Inter-relationships



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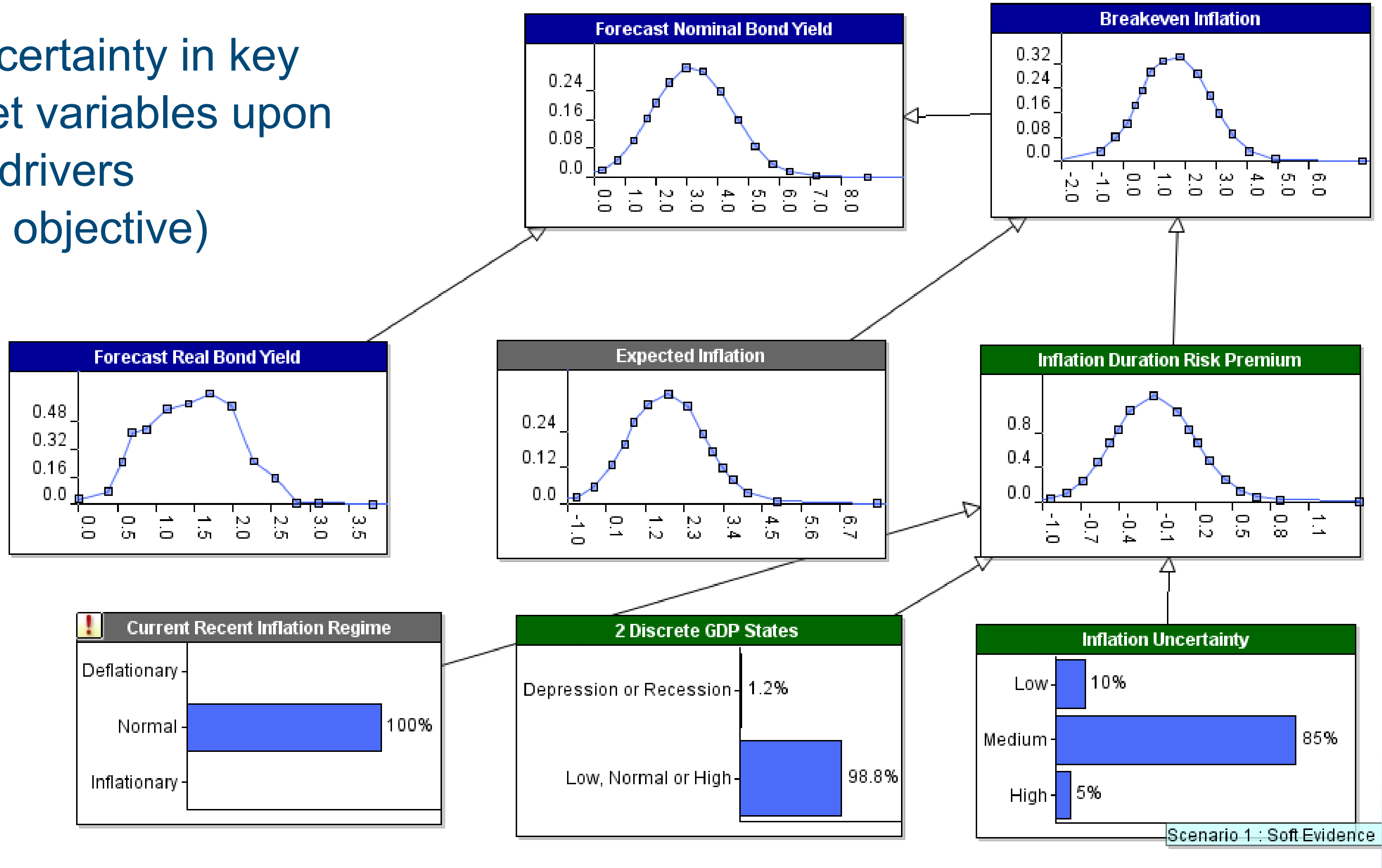
Modelling Full Dynamic Risk Factor Distributions

- Condition uncertainty in key capital market variables upon risk factors / drivers (subjective & objective)



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Questions?

Joshua Corrigan
joshua.corrigan@milliman.com

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