Unravelling the complexity of risk

Society of Actuaries in Ireland

Neil Cantle, Principal Milliman

June 2011

Plan for this session

- Risk
- Overview of complex adaptive systems (CAS)
- Risks as a CAS
- Examples of applications of tools
- Open discussion and questions

Risk

- **Uncertainty** = lack of complete certainty – i.e. existence of more than one possible outcome
- **Risk** = state of uncertainty where some of the possibilities involve an undesirable outcome (e.g. loss)

  Note: Risk is a human artefact

So,

ERM equates to identifying and managing uncertainties relating to undesirable impacts on achieving business goals

Hence

...achieving better business performance

[NOT about avoiding risk]

Motivation For New Approach

- Conceptual framework typically used for risk is flawed
  - Understanding the whole does not follow from understanding pieces
- Risk assessment nearly always relies upon human judgement (lack of data)
  - Humans are not good at assessing risk
- Frameworks provide limited predictive capability
  - Models focus on outcomes not real drivers
- People confuse “Black Swans” and complex risk
- Business has become increasingly complex and techniques are still about linear behaviours and “normal” distributions

Time to evolve...

Where Next For Risk Management?

- Previous study leads us to the view that:
  - Risk tools need to embrace
    - Holism
    - Non-linearity / complexity
    - Human bias
    - Adaptation / evolution
  - Risk can be viewed as the unintended emergent property of a complex adaptive system
  - Risks are a process and even complex risks can be spotted early

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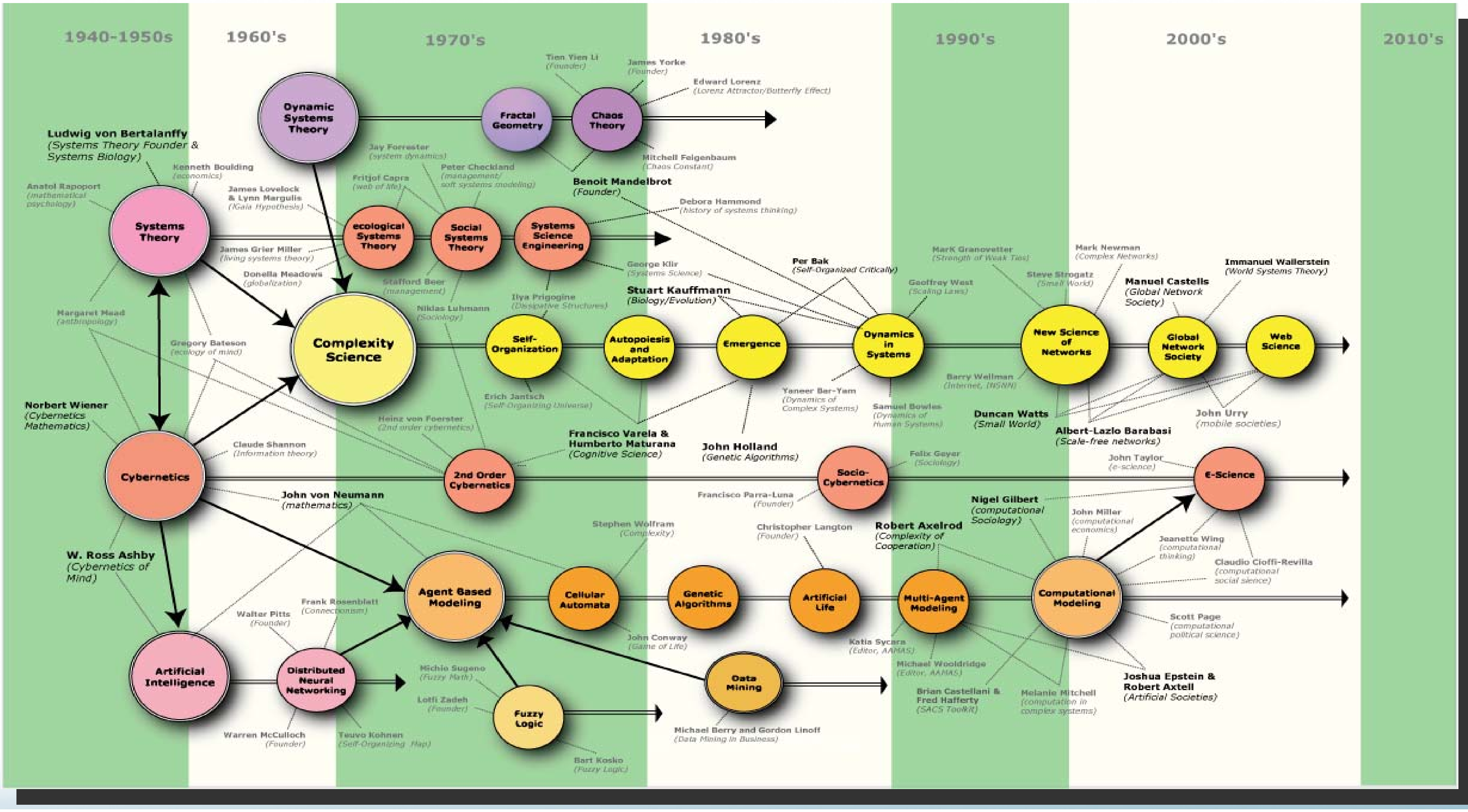
Overview of complex adaptive systems

UNRAVELLING THE COMPLEXITY OF RISK

Roadmap of the development of complexity science



Source: Wikipedia

Systems Thinking

- Systems thinking is both a worldview that:
  - Problems cannot be addressed by reduction of the system
  - System behaviour is about interactions and relationships and
  - Emergent behaviour is a result of those interactions
- And a process or methodology
  - To understanding complex system behaviour
  - To see both the “forest and the trees”
  - Identify possible solutions and system learning
  - Utilises complexity science and other disciplines

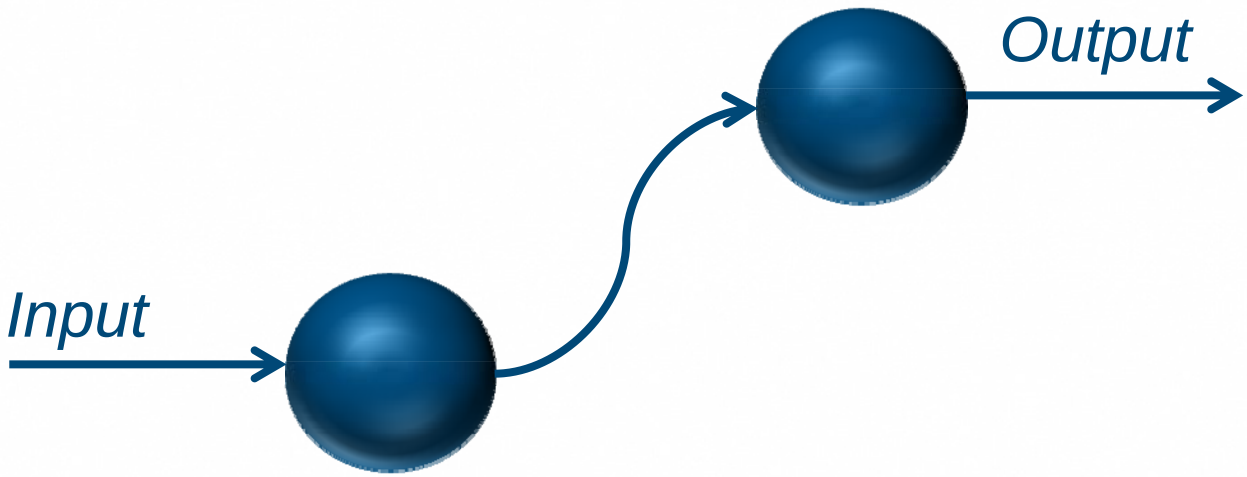
Complexity and complex systems

The development of complexity science is a shift in scientific approach towards an interdisciplinary paradigm with the potential to profoundly affect business, organisations and government.

The goal of complexity science is to understand complex systems: what ”rules” govern their behaviour, how they manage change, learn efficiently and optimise their own behaviour.

Schuh et. al.

Introduction to Systems



A set of components interconnected for a purpose

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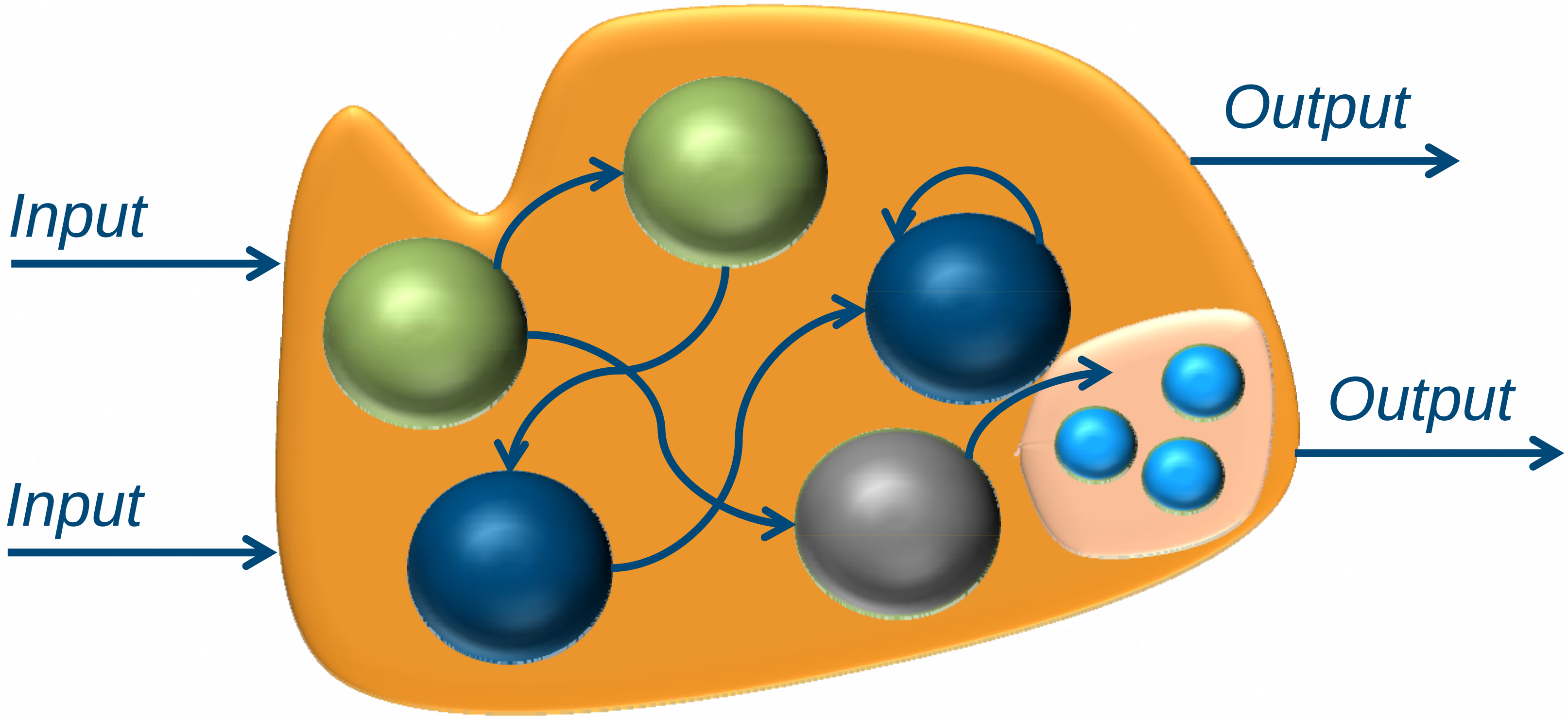
Introduction to Systems



Complex System – Feedback, subsystems, etc.

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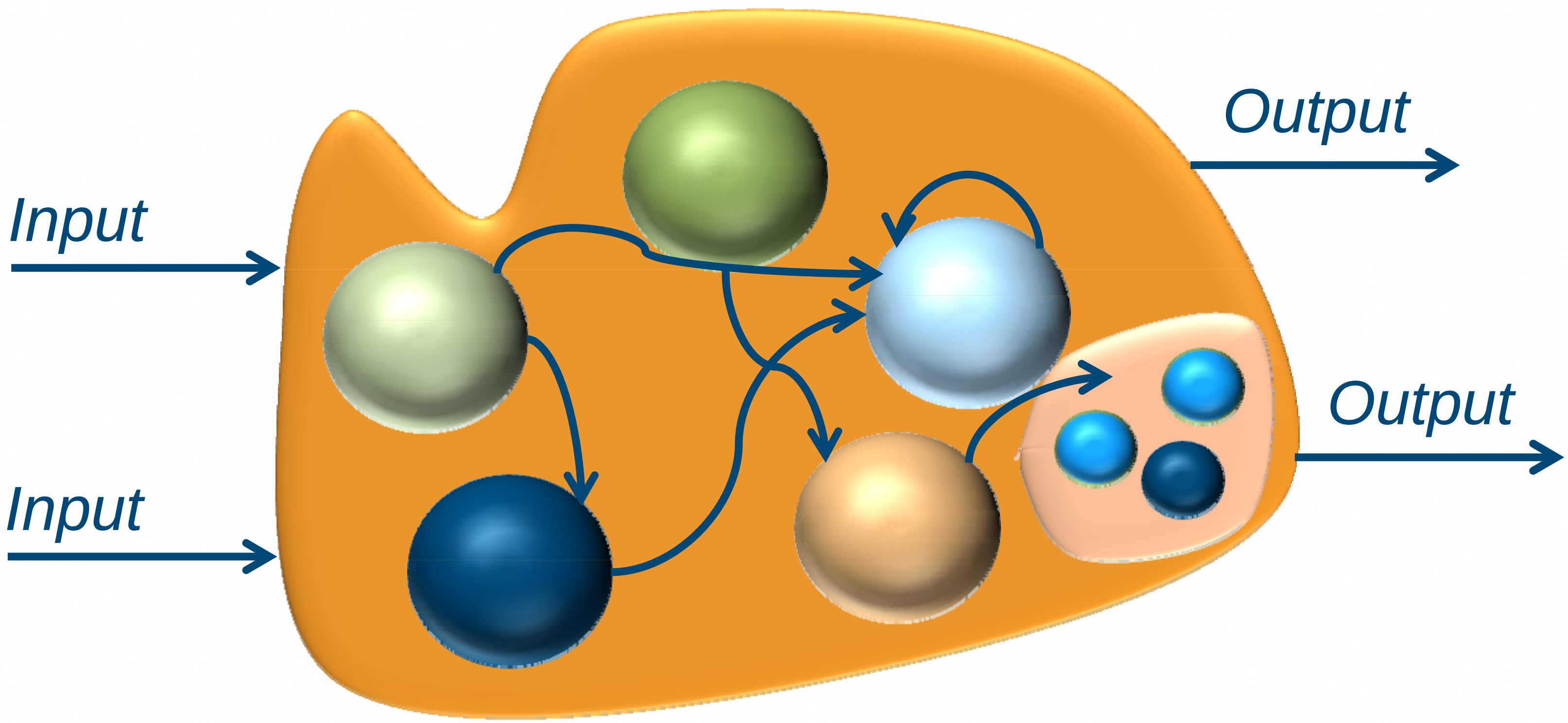
Introduction to Systems



Complex Adaptive System – Structure changes

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Complex Adaptive Systems

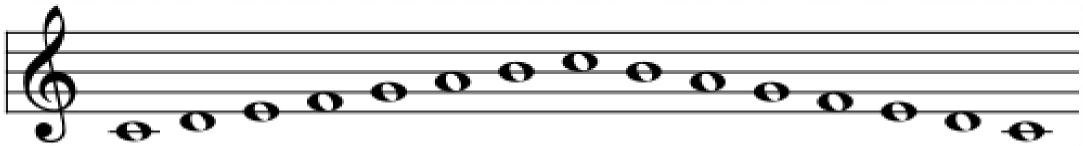
- Examples:
  - Sand Pile
  - Immune system
  - Weather system
  - Forests
  - Birds flocking
  - Organisations
  - Supply chains
  - Fish stocks
  - ERM

Complex Adaptive System Characteristics

- Has a purpose
- Emergence – the whole has properties not held by sub components
- Self Organisation – structure and hierarchy but few leverage points
- Interacting feedback loops – causing highly non-linear behaviour
- Counter-intuitive and non-intended consequences
- Has tipping point or critical complexity limit before collapse
- Evolves and history is important
- Cause and symptom separated in time and space

Emergence – E.g. Music

You can explore the characteristics of individual notes...



...but you cannot know the tune without knowing the interactions (score)

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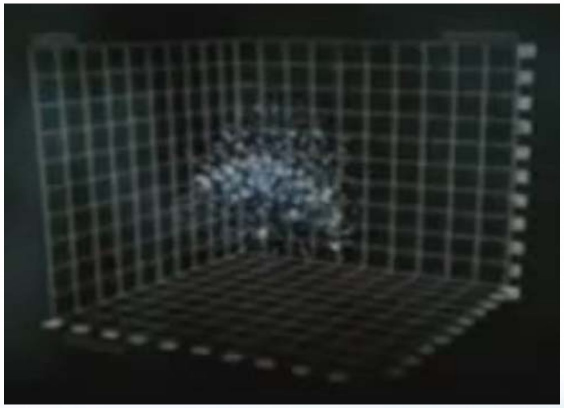
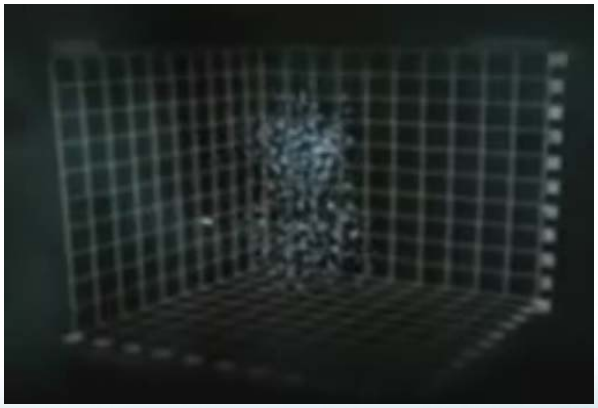
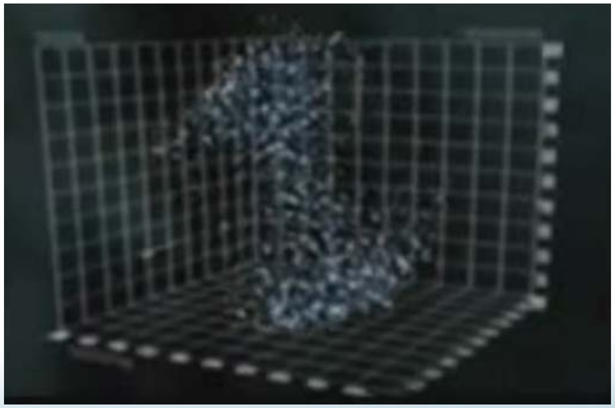
Self-Organisation and emergence



Modelling complexity need not be complex:

These highly complex behaviours can be reproduced quite accurately with 4 simple, interacting rules

1. Only aware of nearest neighbour... 2. Line up... 3. Attracted/small distance apart... 4. Danger!...Get out of the way

Source: Strogatz, Synchrony

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Unintended consequences

- People “understand” bits of risk, not the whole thing

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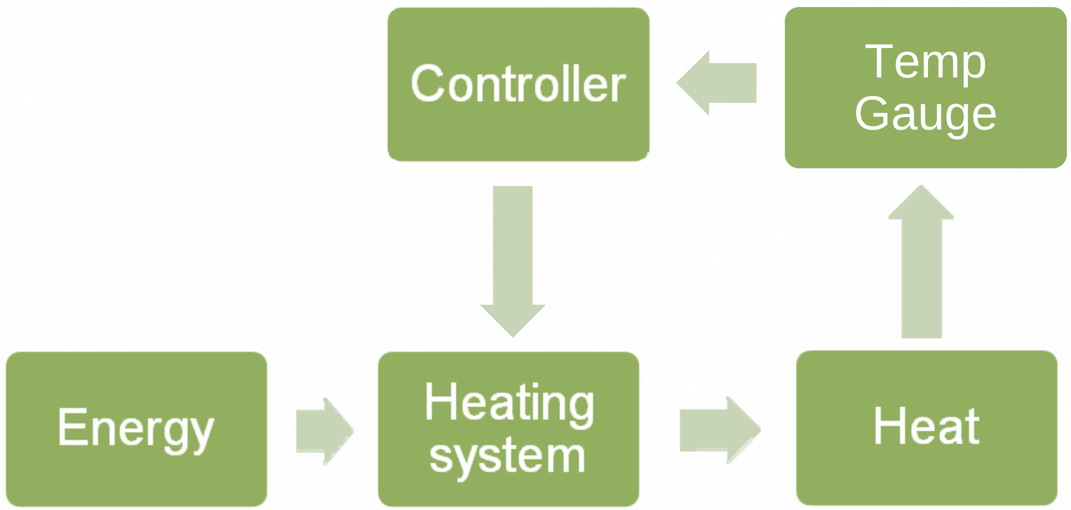
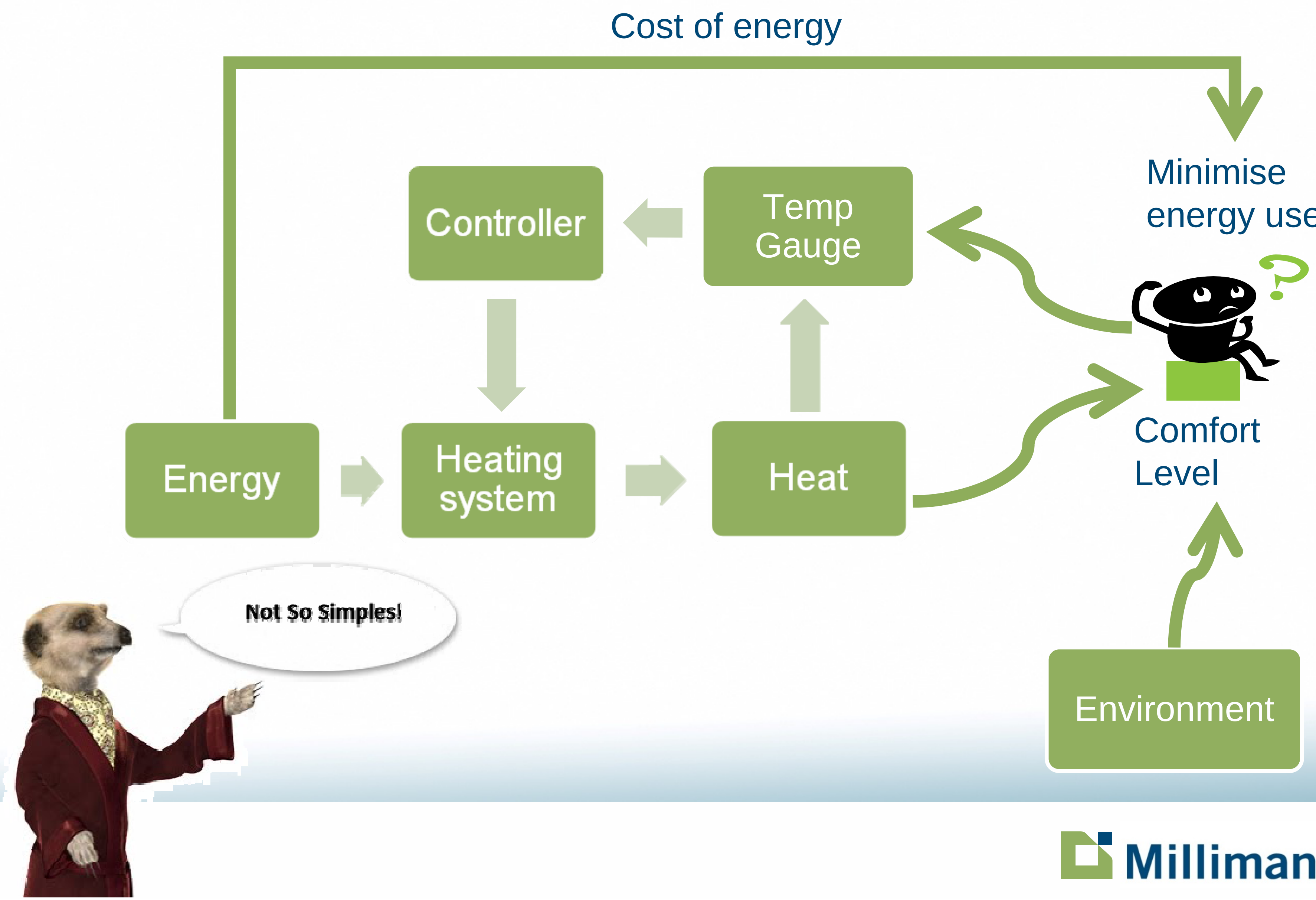
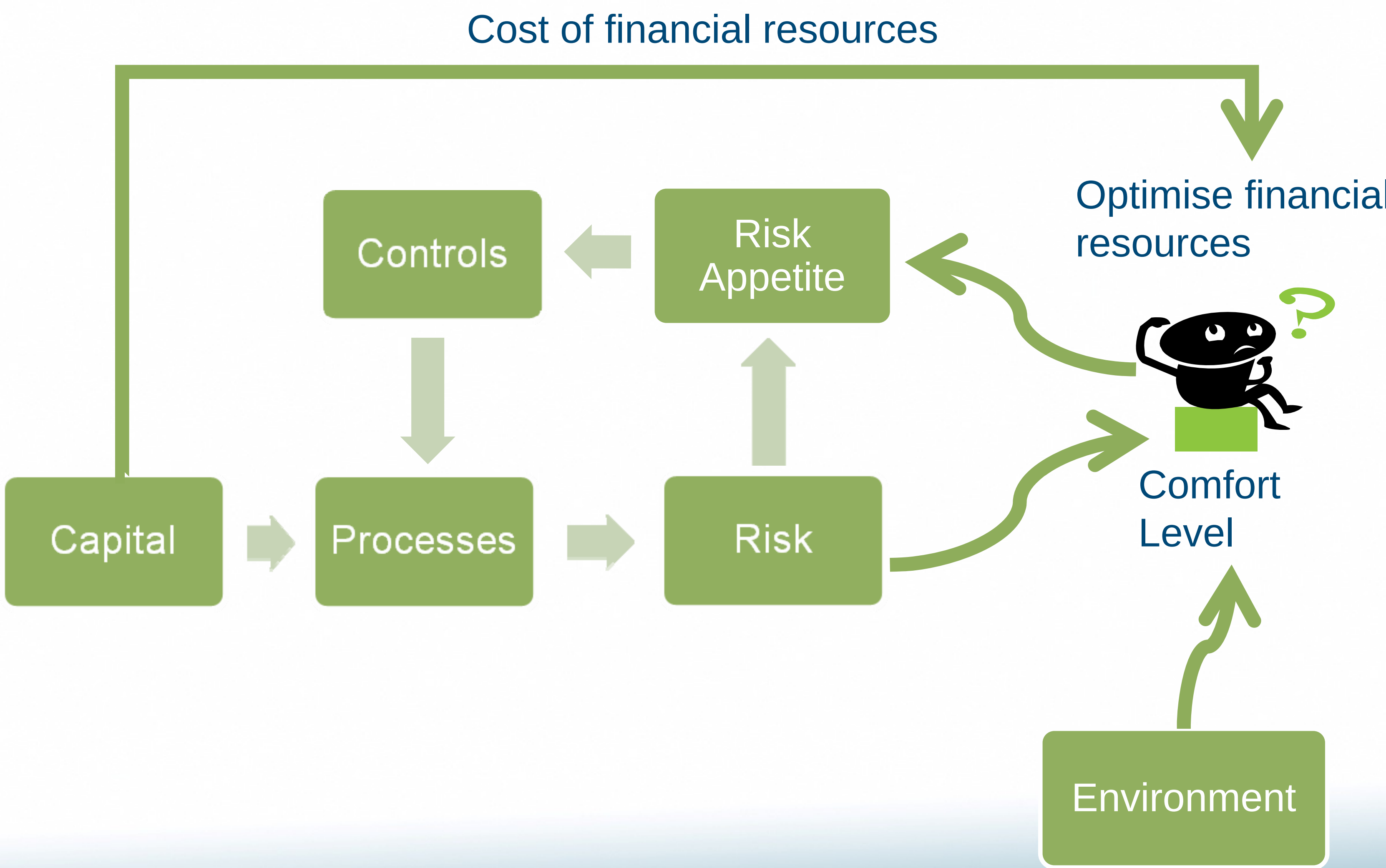
Idealised heating system



Real world heating system



Business as a heating system



Recap – Complex Adaptive Systems

- Systems theory is a structured way to describe a set of interacting components which have a purpose
- Complex adaptive systems (CAS) have defined properties
- The study of CAS is interdisciplinary – so are applicable tools
- Complex behaviour can arise from simple rules
- Emergence requires a holistic approach before studying parts
- Important to know a system's critical complexity trajectory

Can risks be modelled as a complex adaptive system?

UNRAVELLING THE COMPLEXITY OF RISK

The human factor: Company = CAS

"There can no longer be any doubt that the micro assumptions of [economic] theory – the assumptions of perfect rationality – are contrary to fact. It is not a question of approximation; they do not even remotely describe the process that human beings use for making decisions in complex situations."

Herbert Simon 1979

"How do humans reason in situations that are complicated or ill-defined? Modern psychology tells that as humans we are only moderately good at deductive logic, and we make only moderate use of it. But we are superb at seeing or recognising or matching patterns – behaviours that confer obvious evolutionary benefits. In problems of complication, then, we look for patterns."

Brian Arthur "Inductive reasoning and bounded rationality" American Economic Review 84 #2 (1994)

Applied to risk

- Risk is the unintended emergent property of a CAS
- Risk is a process which emerges over time from the complex interactions of many factors
- Risk has multiple-characteristics
- Risk has structure and hierarchy
- Human bias is highly prevalent in assessing risk
- Emerging risk is an evolutionary function of the past system performance

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Level of Understanding

Symptoms

↓

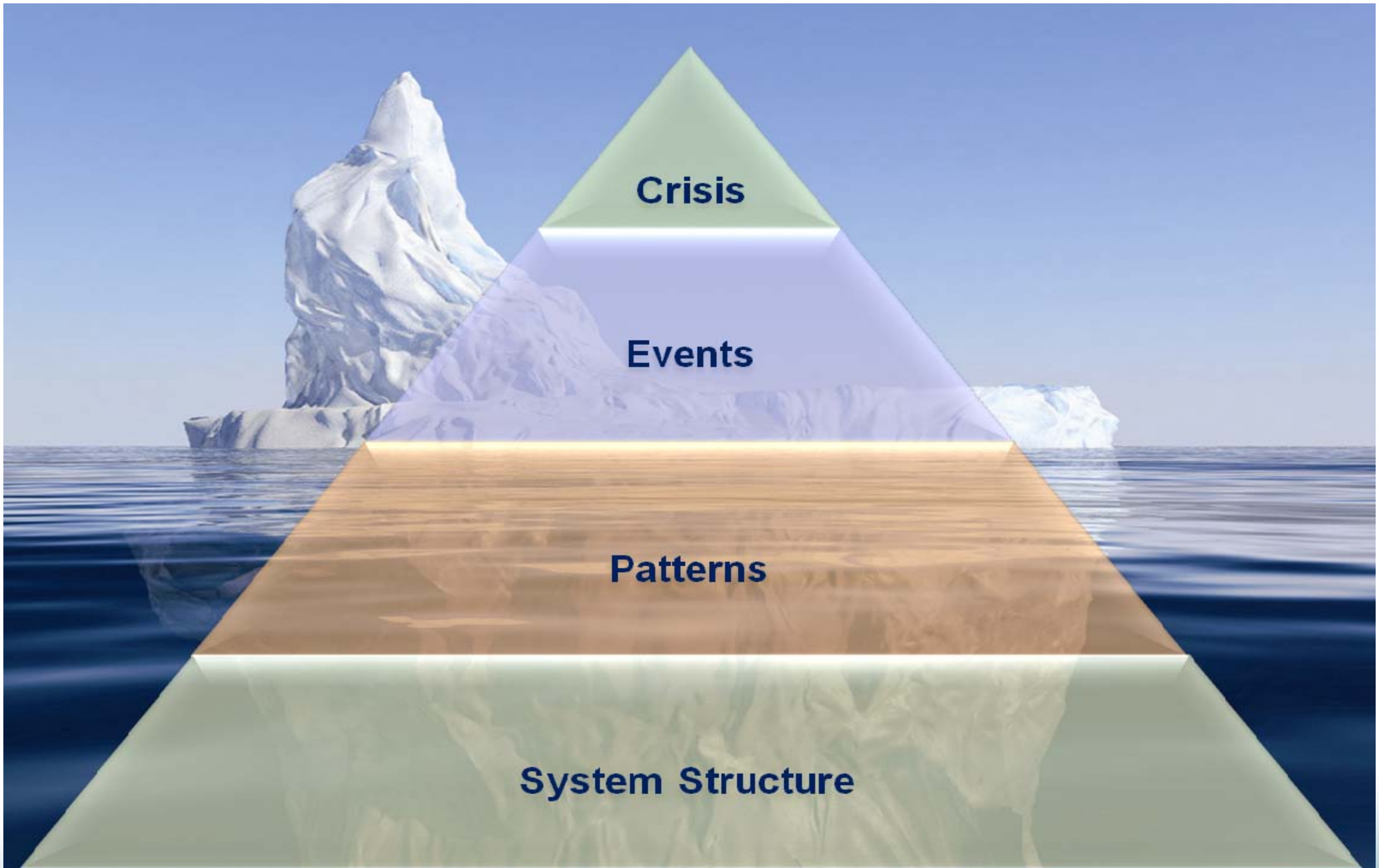
Causes

↓

Sense-making

↓

Understanding



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Examples of applications of tools

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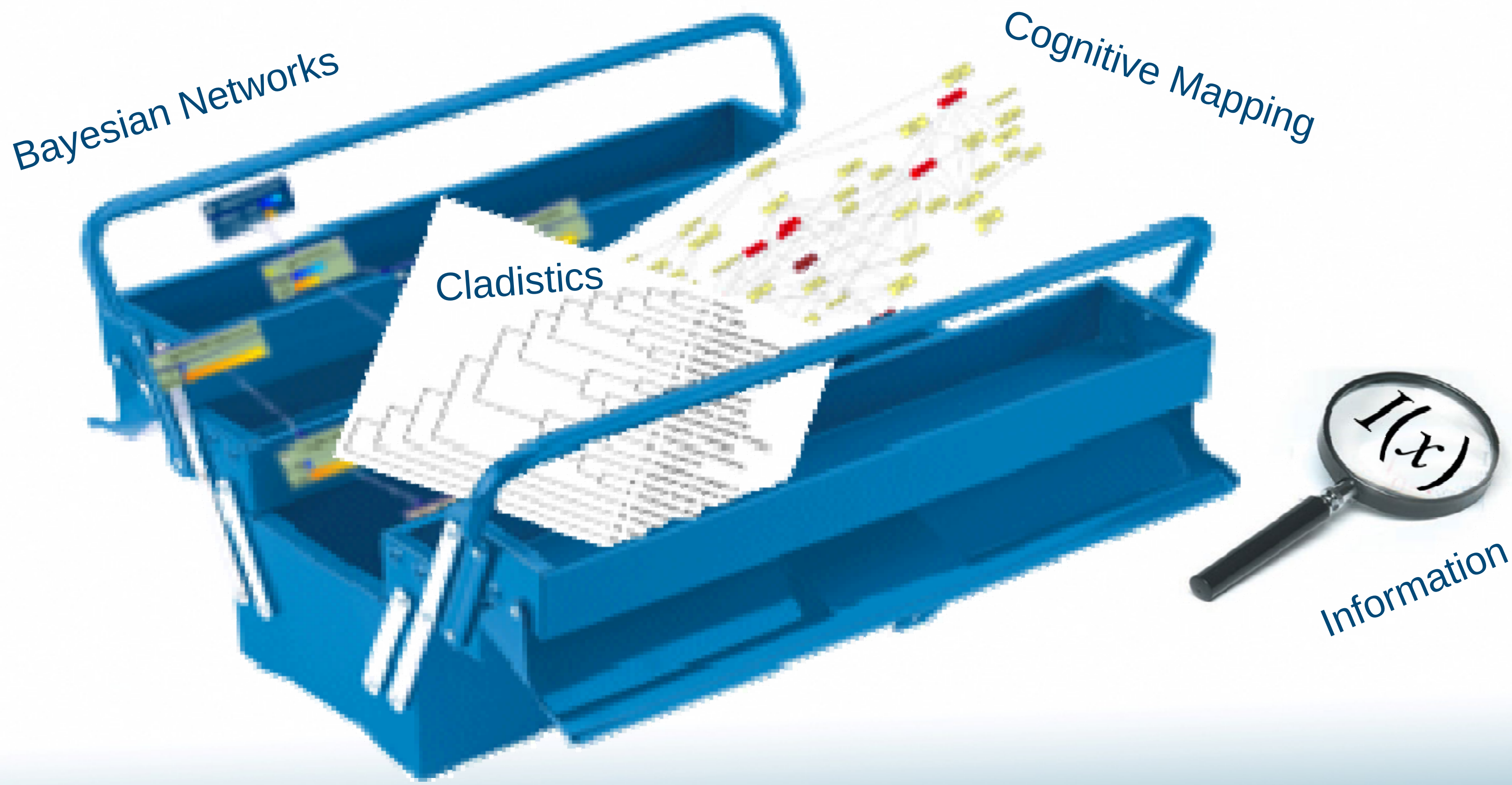
Some available tools



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Understanding Your Risk Profile

- How is your business to be achieved?
- What factors support success?
- What factors inhibit success?
- How are the factors related?
- What are the dynamics of various factors?
- How do I make sense of so many different interacting factors?

- Holistic view...look for patterns...make sense...isolate key dynamics

Labelling Data

- What colour is this Monet?
  - Purple?
  - Green?

The Artist's Garden at Giverny

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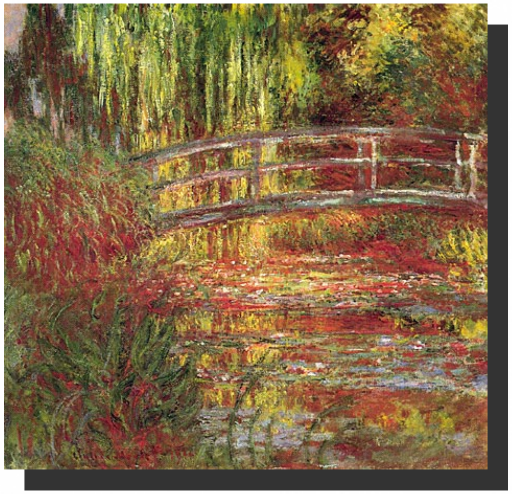
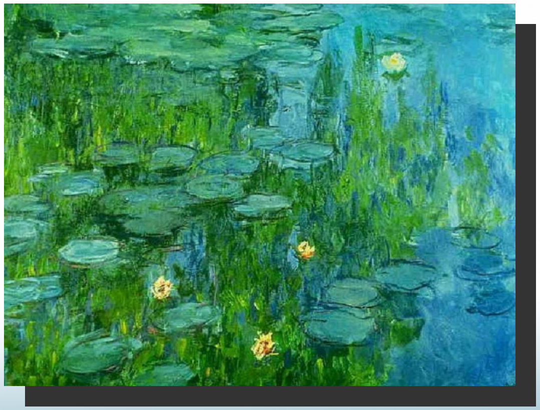
Labelling Data

These both have bridges



They all have lilies

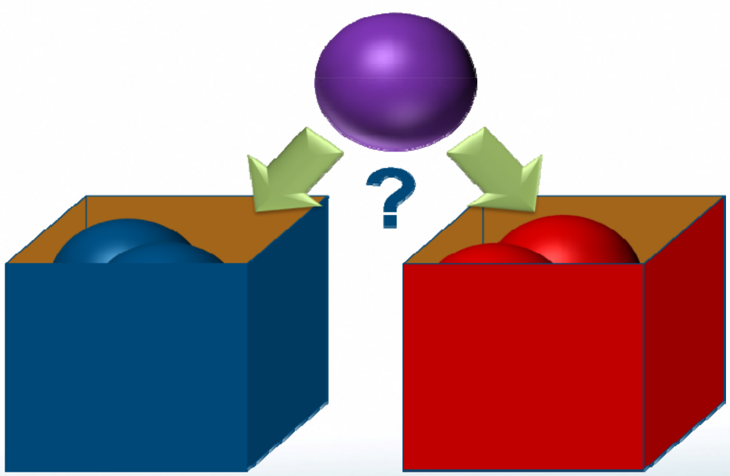
These have similar colours



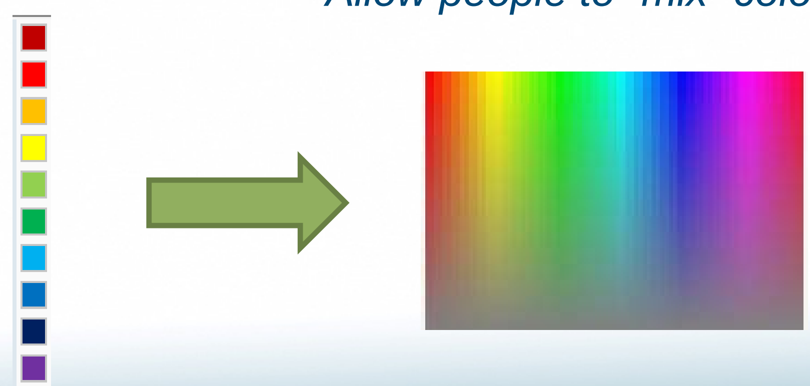
It is clear to a human eye that these paintings have something in common, because we are using multiple characteristics to compare them

Don’t oversimplify too soon

- Looking for patterns needs information
- Many attempts to monitor risk throw that away at outset
- Don’t guess in advance what you expect to see
- Need a “model-free” approach to see emergence



Allow people to “mix” colours



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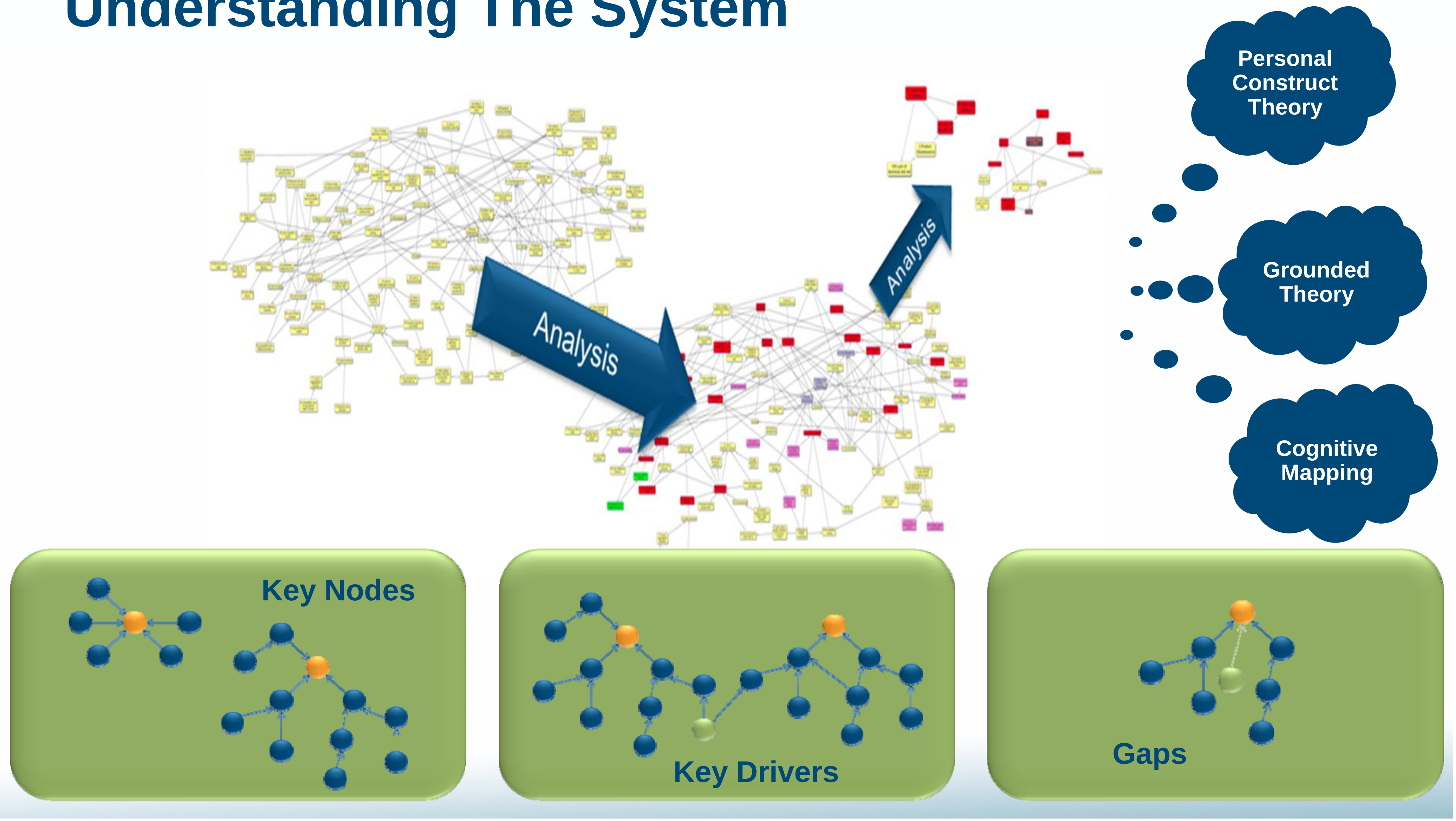
Understanding The System



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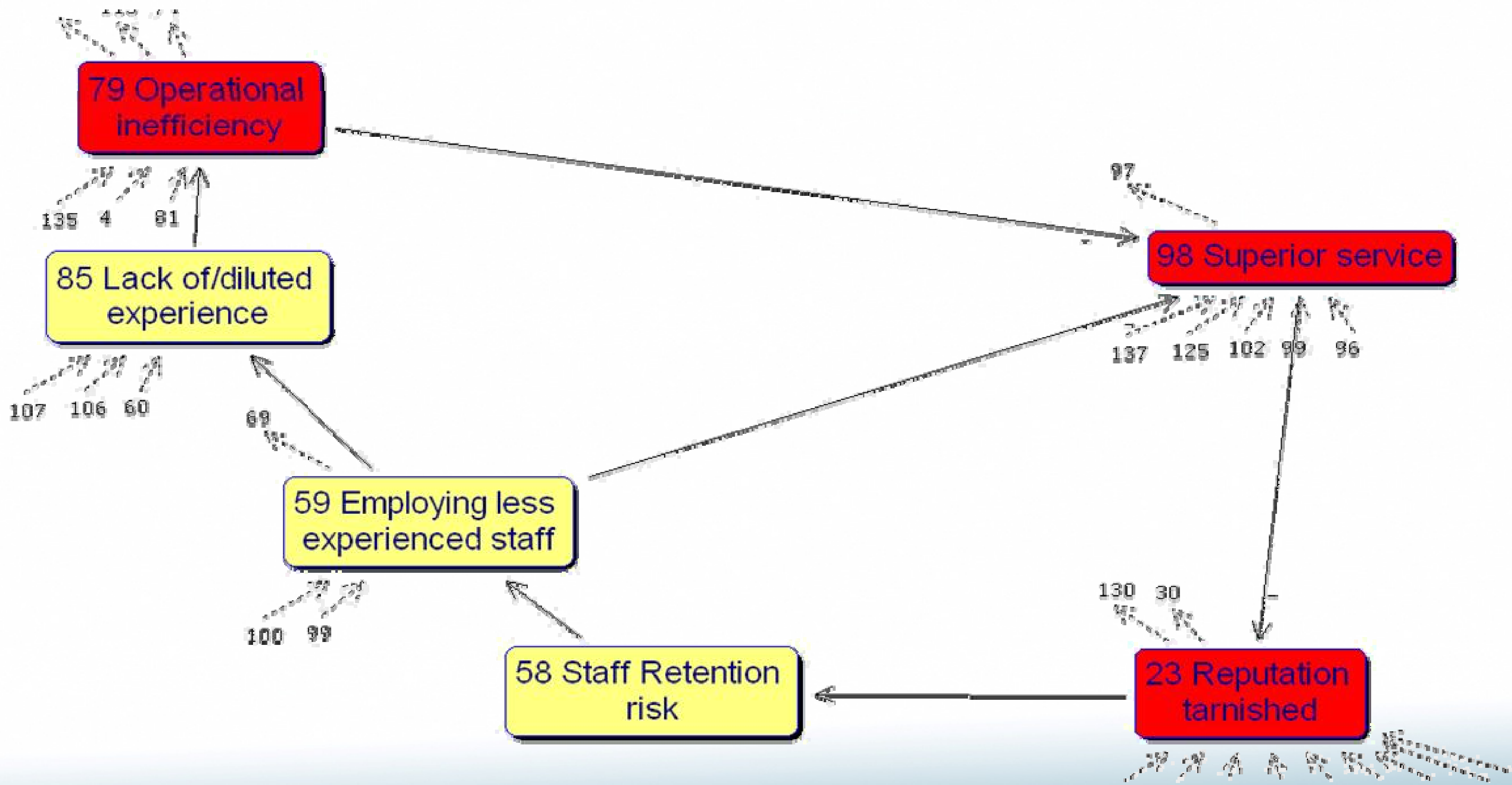
A Dynamic Loop From Cognitive Map



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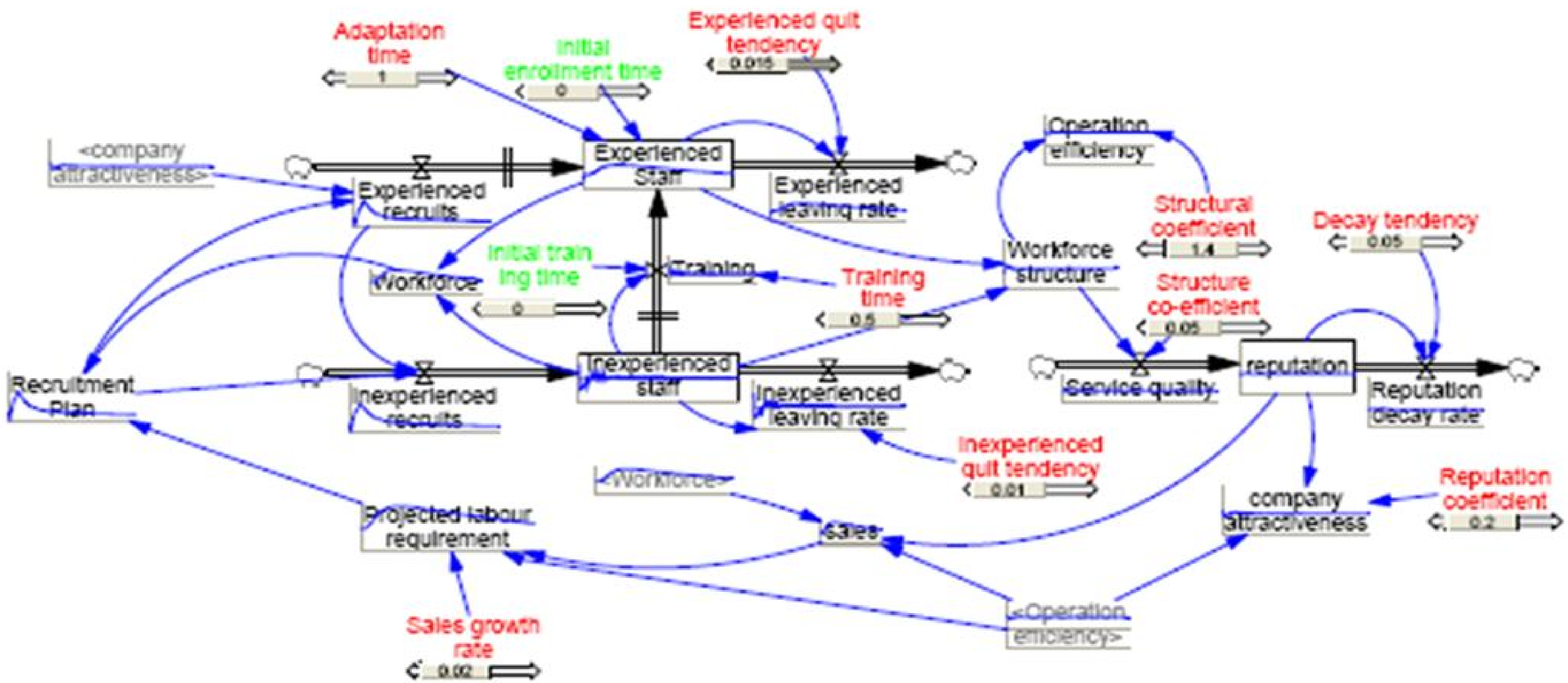
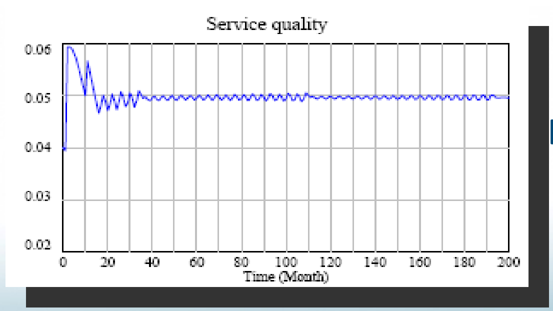
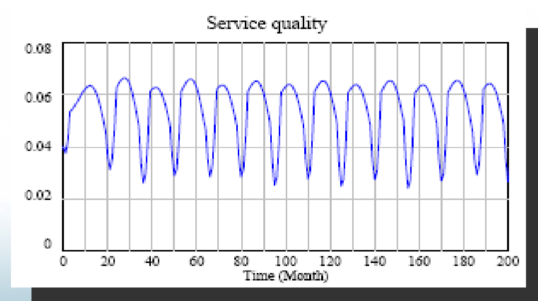
Can Be Modelled With Systems Dynamics



A small change in training time and experienced leaver rate has dramatic impact on service quality...





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Applications

- Risk profile analysis (e.g. For ORSA)
- Emerging risk identification
- Risk appetite setting
- Reverse stress testing

Entropy/Uncertainty

- Measuring the information content (Shannon entropy) of system tells us whether performance is making sense
- Information $I(x)$ = - log $p(x)$
- Entropy = average information = $-\Sigma\ p(x)$ log $p(x)$
- Intuition – high entropy = high uncertainty:
  - Impossible event ($p(x)$=0) is surprising ($I(x) = \infty$)
  - Certain event ($p(x)$=1) is not interesting ($I(x)$ = 0)
- Through understanding your "system", identify relevant variables to monitor
- If their information content is high/volatile you need to know why

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Checking Relationships

- Correlation:
  - Typical measures capture linear dependence
  - Calculated with reference to changes in second moment
  - Compare joint change with individual changes
  - E.g. Pearson,

$$\rho_{X,Y} = \frac{\operatorname{cov}(X,Y)}{\sigma_X \sigma_Y}$$

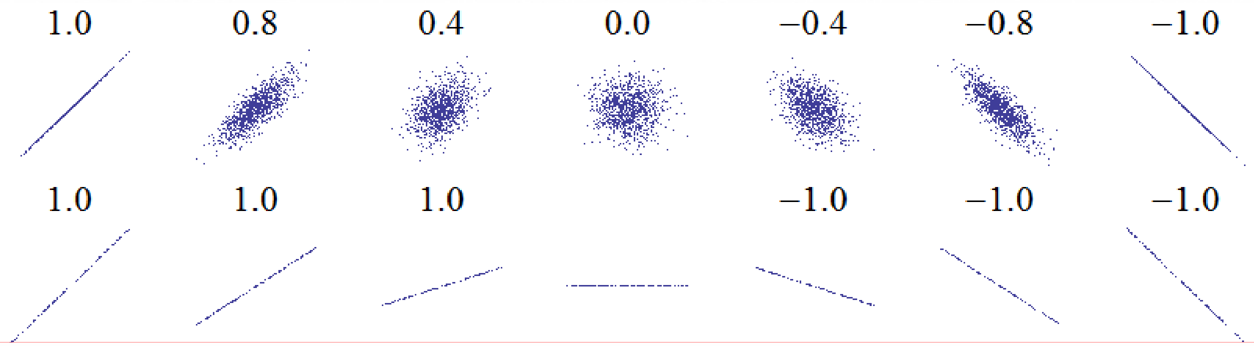
- Non-linear dependence needs us to look at more moments
  - Mutual information

$$I(X,Y) = \int_X \int_Y p(x,y) \log \frac{p(x,y)}{p_1(x)\,p_2(y)}\, dx\, dy$$

Non-linear relationships

- Are we still talking?

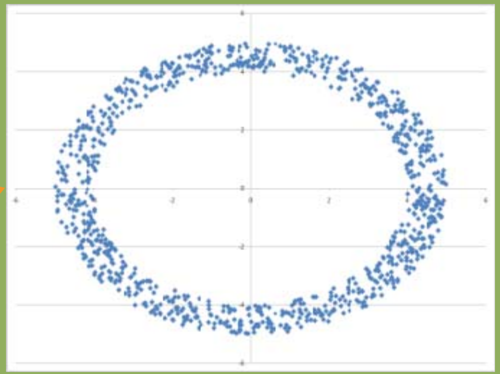
Different levels of correlation



<u>Example</u>

Θ ~ U[0,2π]
R ~ U[4, 5]
X = R cos Θ
Y = R sin Θ

Sample of 1000



Correlation = 0.0
Mutual Info = 1.0

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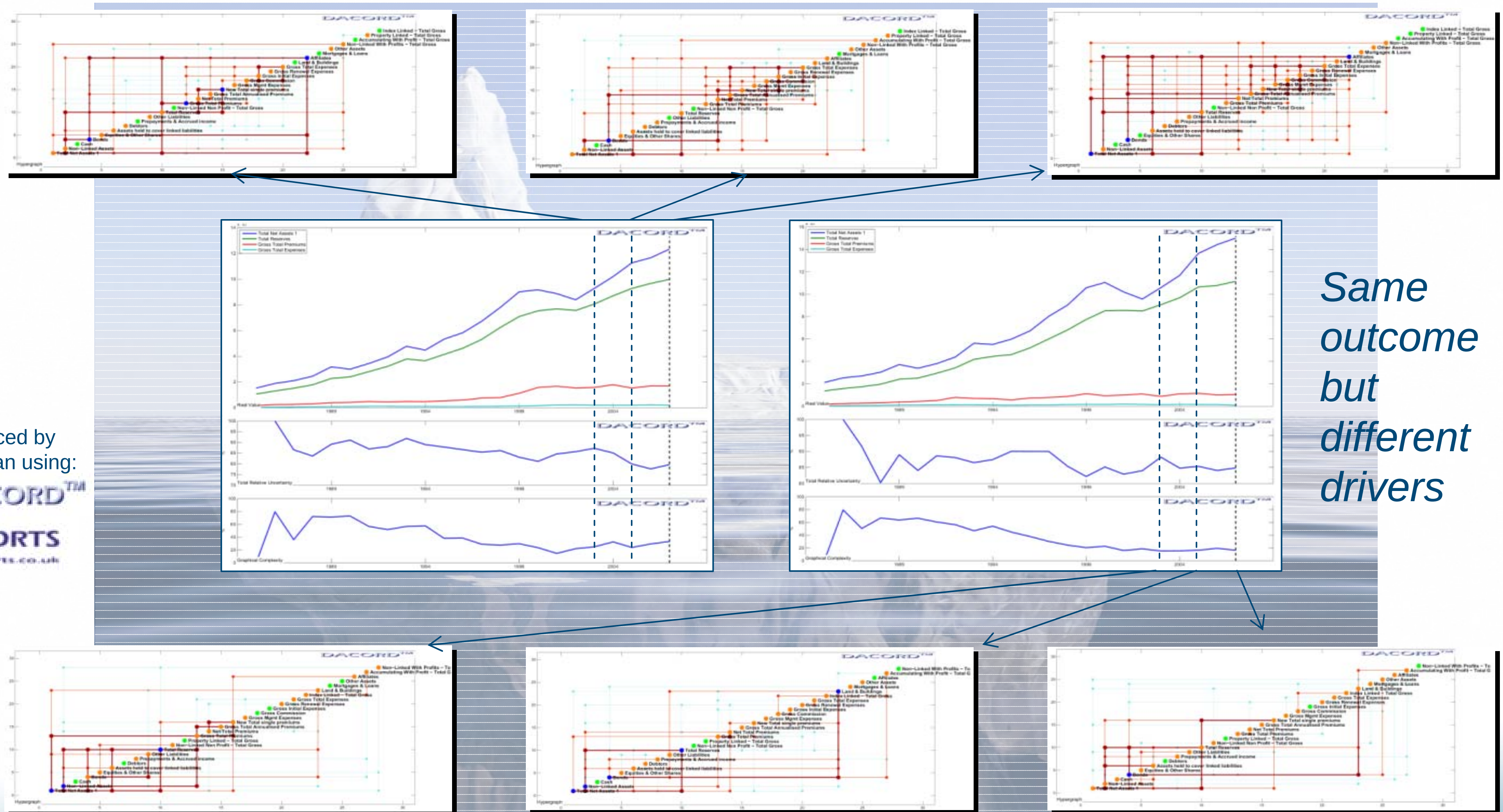
Looking beneath the surface



Same outcome but different drivers

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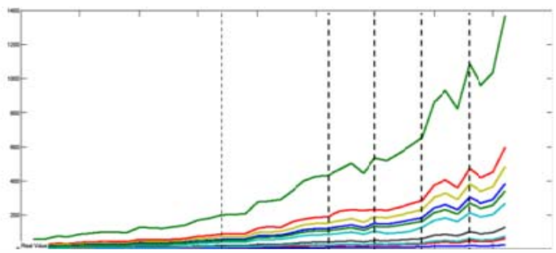
Uncovering hidden changes



Trend of SCR components looks stable over time...

...but uncertainty differs between components...

...and overall uncertainty changes over time...

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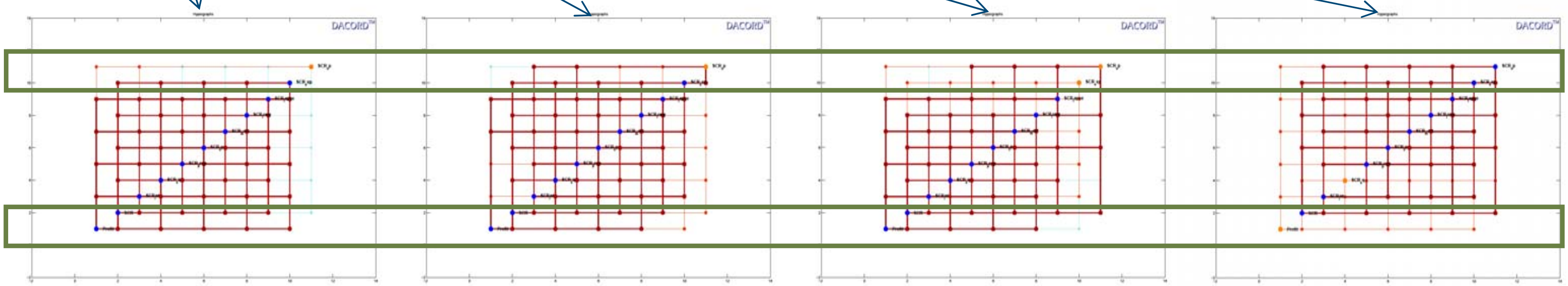
OpRisk gets more important

EqRisk gets less important



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Influence Modelling

- Lower frequency events tend to be quite heterogeneous
- Statistical models therefore problematic from outset
- More “correct” to model according to underlying cause
- Bayesian Networks can be used to capture expert knowledge of risk behaviour
- No need to correlate events, simply link by common cause
- Wide range of sophistication possible
- Good way to integrate expert knowledge with observed outcomes

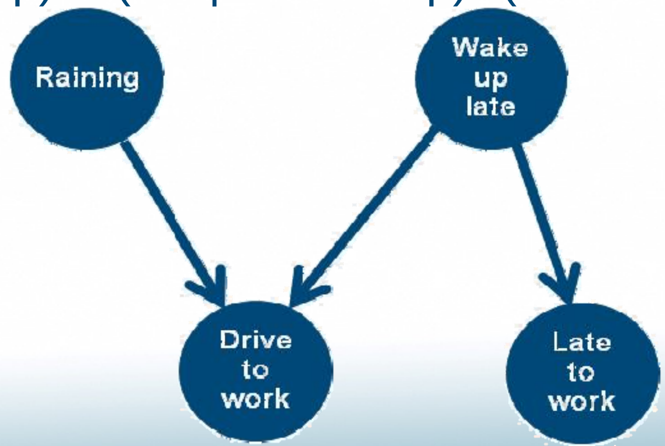
Theory – Bayesian Networks

- Bayesian Networks use conditional probabilities to build up a picture of some final outcome
- If we observe someone being late to work we can update our view of how likely it is that they overslept

$$P(\text{o'sleep} \mid \text{late}) = P(\text{late} \mid \text{o'sleep})\, P(\text{o'sleep}) \,/\, P(\text{late})$$

$$= \frac{P(\text{late} \mid \text{o'sleep})\, P(\text{o'sleep})}{P(\text{late}|\text{o'sleep})P(\text{o'sleep}) + P(\text{late}|\textit{not}\ \text{o'sleep})P(\textit{not}\ \text{o'sleep})}$$

Bayes' Theorem helps us to express the probabilities of outcomes in terms of preceding events and their likelihood



Theory – Bayesian Networks (2)

- Inference can be used to make sense of evidence in the model
- In our example, suppose that knowing the person is late leads us to having a higher posterior view of the probability that they overslept
- The probability of them driving is now also affected

$$P(D)=P(D|R,O)P(R)P(O)+P(D|R',O)P(R')P(O)+P(D|R,O')P(R)P(O')+P(D|R',O')P(R')P(O')$$

D=drive
R=rain
O=overslept

- Knowing that the person was late increases P(O) so the chance of them driving has also increased
- If we suppose that rain was originally the most likely cause of the person driving, the additional knowledge that they are also late could shift the balance so we now know that they actually overslept

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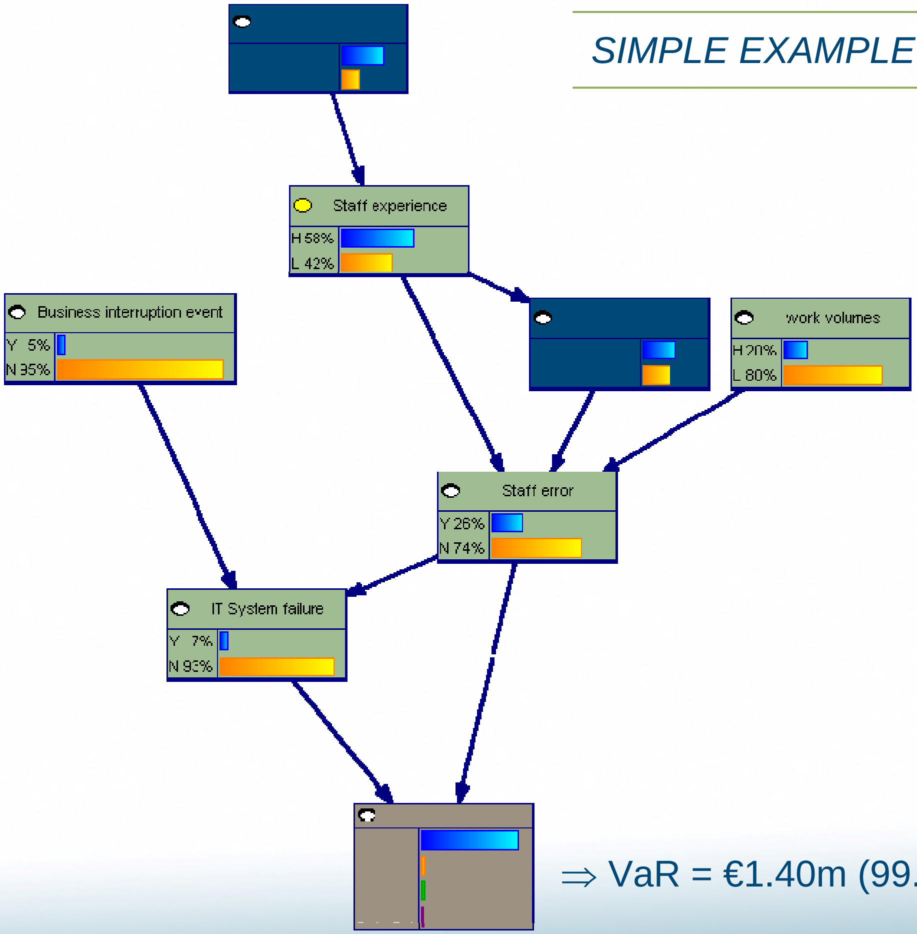
Bayesian Networks

- Permits more transparency and better engagement from business
- Combinations of earlier tools can help to determine relevant key drivers of risk outcome



SIMPLE EXAMPLE

⇒ VaR = €1.40m (99.5%)

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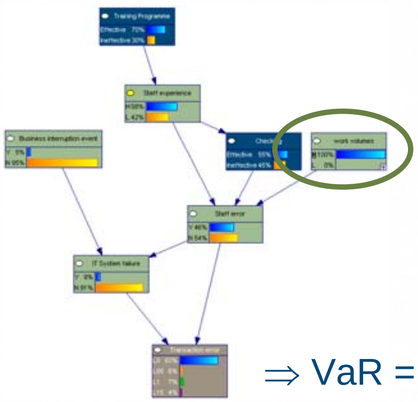
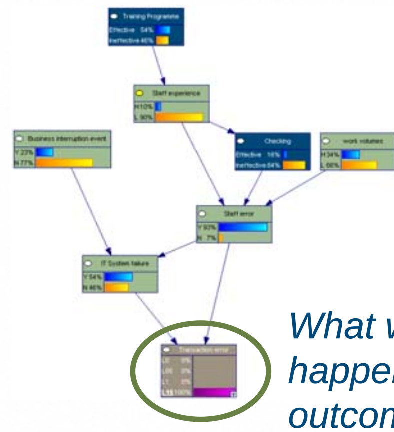
Bayesian Networks (2)



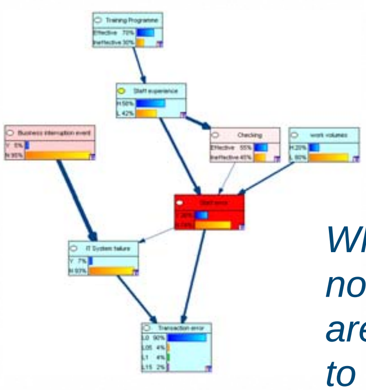
What if work volumes are high?

⇒ VaR = €1.44m (99.5%)

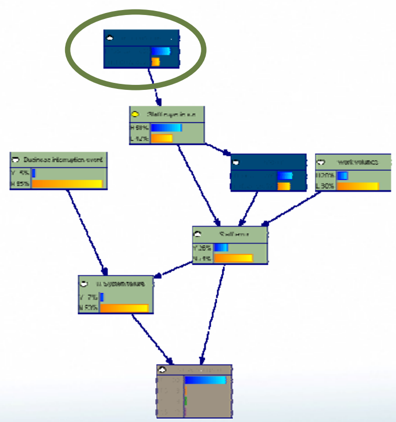


"Evidence" of outcome propagates back up the model

What would need to happen for worst outcome to occur?



Which nodes/connections are most significant to outcome?



Experts initially guess training is 60-80% effective and 25-35% ineffective
Parameterise model at 70%/30%

Observe 80% effective over past year

Update distribution to 71%/29%
(assumes expert guess follows Dirichlet distribution)

Implemented in GeNIe

Risk Appetite

- UK Actuarial Profession commissioned research into risk appetite and emerging risk
- Milliman and the University of Bristol have been carrying out that research
- Results presented at Risk & Investment Conference, June 2011
- Papers to be published shortly

From the top

The Actuarial Profession
making financial sense of the future

- Dimensions of risk appetite
  - Balance sheet
  - “Flow” e.g. Profit, member return
  - Non-financial e.g. Reputation, social impact
- Centred on key values of Board
- Express acceptable amount and sources of risk

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From the top

The Actuarial Profession
making financial sense of the future

Examples:

- The Board expects to maintain sufficient capital during normal conditions to retain a AA rating
- Following a 1:25 year event the Board expects to have sufficient capital to retain at least a BBB rating

} e.g. Equivalent to holding c138% of SCR

- During normal conditions the planned profit will be delivered
- Following a 1:10 year event, at least 75% of the planned profit will be delivered

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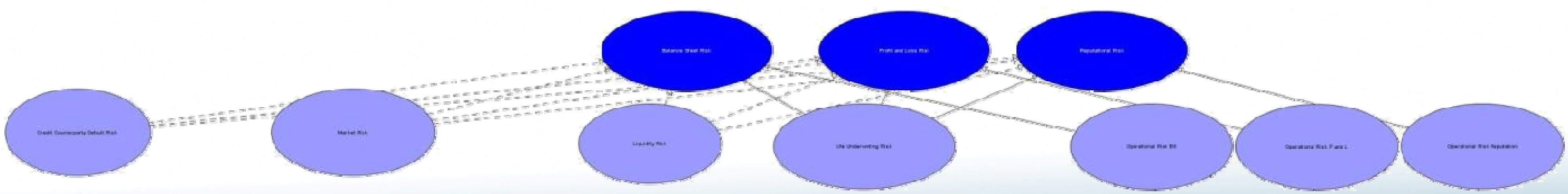
Sources of risk

The Actuarial Profession
making financial sense of the future

- Insurance example:
  - Market
  - Credit counterparty default
  - Liquidity
  - Underwriting
  - Operational

Contribution of each risk to overall position set referring to results from capital/profit modelling and expert judgement

Can be "learned" if sufficient data available.



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Sources of risk

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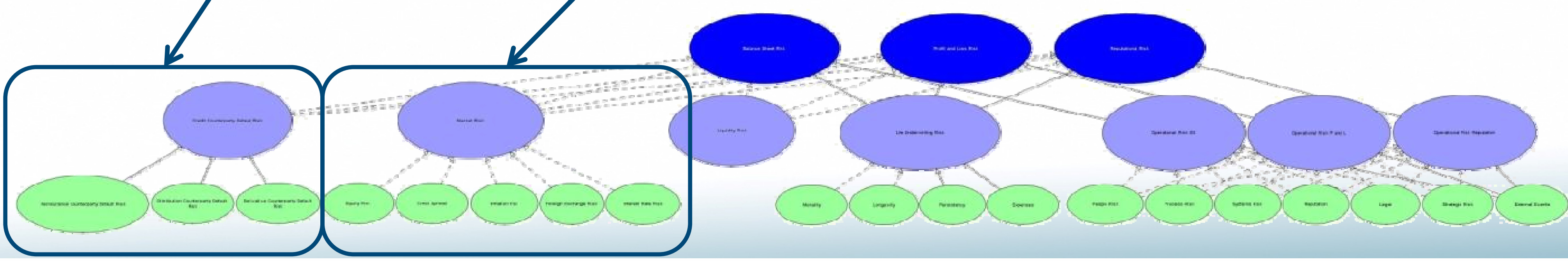
- Credit:
  - Reins cpty
  - Distribution cpty
  - Derivative cpty

- Market:
  - Equity
  - Credit spread
  - Inflation
  - Foreign exchange
  - Interest



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Sources of risk

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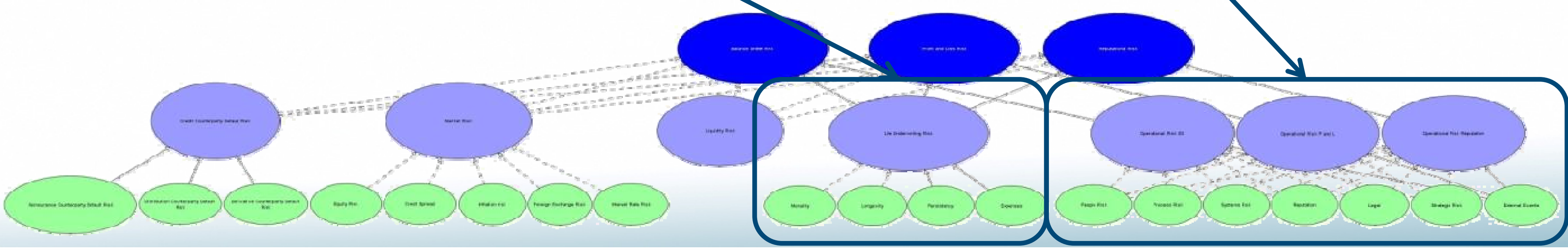
- Underwriting (life):
  - Mortality
  - Longevity
  - Expenses
  - Lapse

- Operational:
  - People
  - Processes
  - Systems
  - Reputation
  - Legal
  - Strategic
  - External events



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Joining top to bottom

The Actuarial Profession
making financial sense of the future

- Determine measurable indicators for risk types
- Identify indicator values for different levels of risk
  - If credit risk was high what level of BBB might we be holding?
  - If process risk was high how many open audit issues?
  - If people risk was low how many people's roles are properly aligned to their expertise?
- Consider whether indicators might be indicative of more than one type of risk

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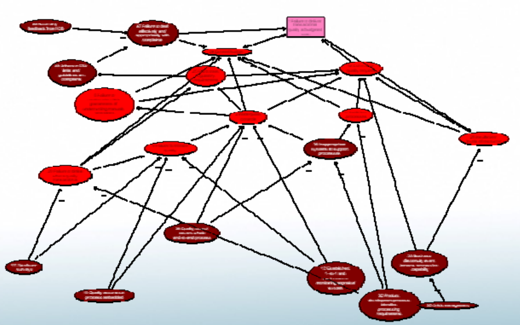
Identifying indicators

- Use a combination of cognitive and data-driven methods
- Leverage expert knowledge using cognitive mapping
  - Workshop with experts to describe risk dynamics
  - Note management actions/controls
  - Describe observable outcomes of drivers
  - Convert workshop discussion into cognitive map
  - Analyse map to elicit key features
  - Propose candidate indicators
  - Confirmation from experts

Cognitive Maps

The Actuarial Profession
making financial sense of the future

- Capture expert understanding of risk
- Full non-linear description
- Combines multiple perspectives
- Reduces/eliminates bias
- Mathematical analysis to determine most connected nodes (local/global)
- Identify “gaps”
- Study key dynamics
- Elicit key indicators



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Checking indicators

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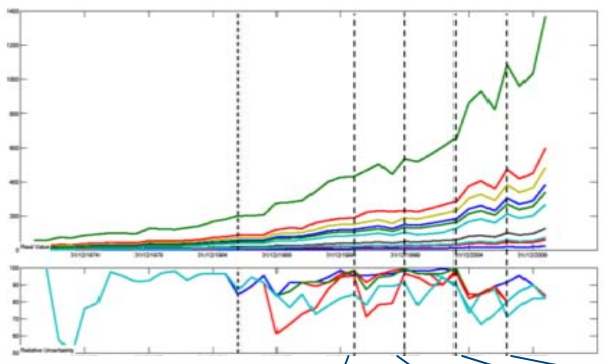

- If we have data, we can use information theory measures, such as mutual information, to determine relevance of indicators

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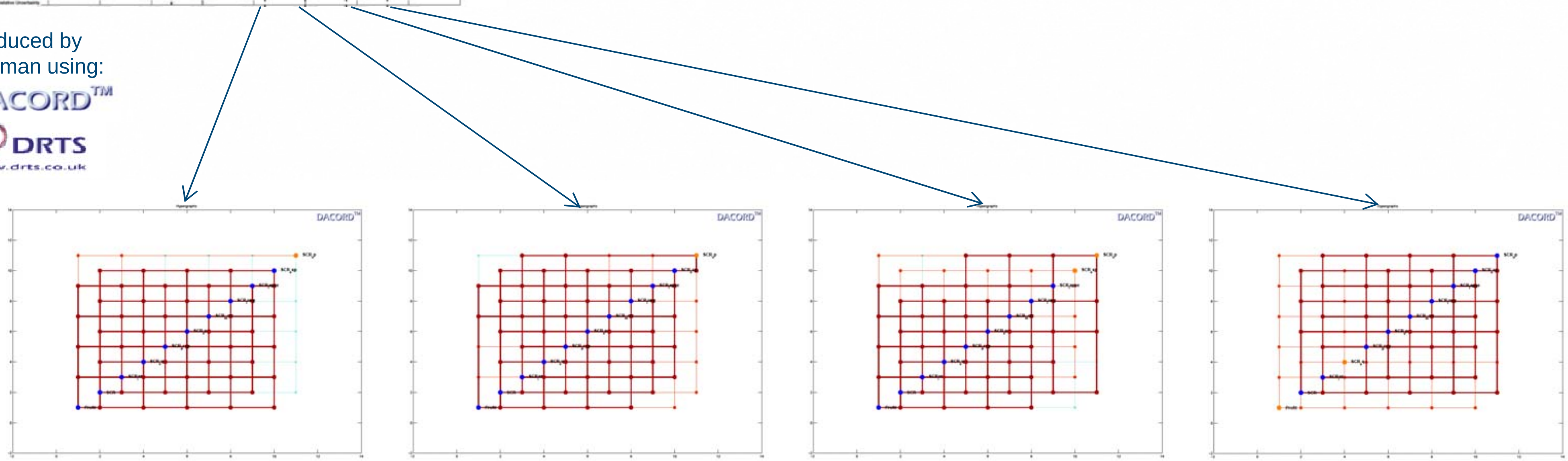

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Sources of risk

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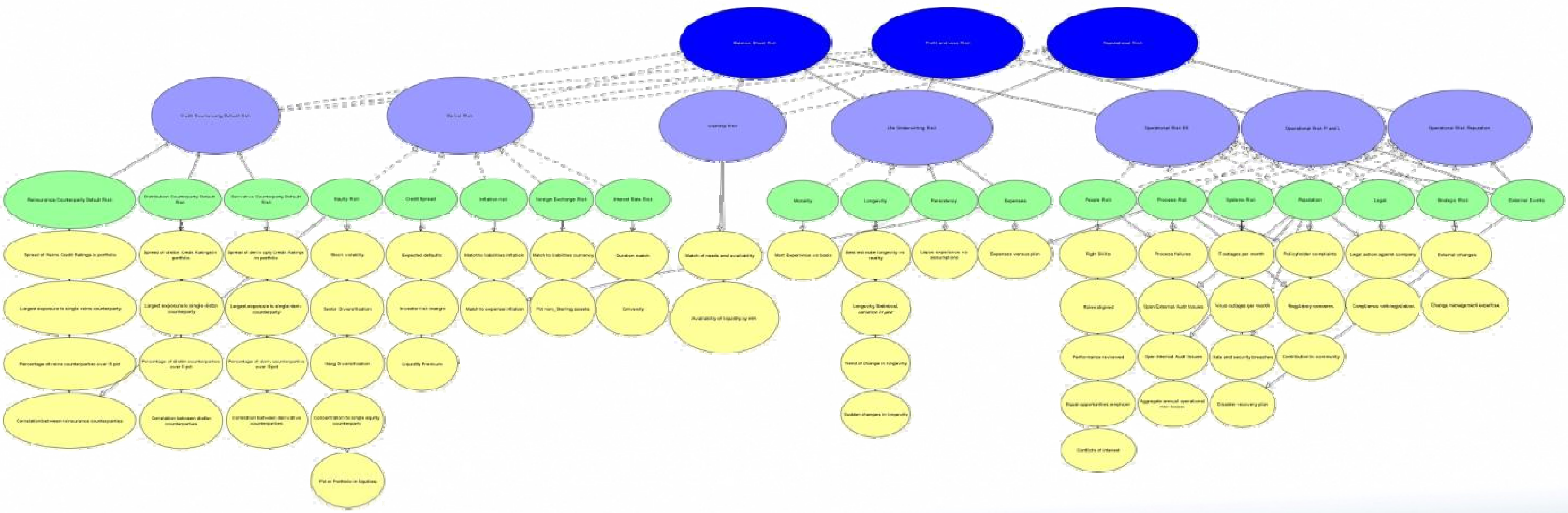
- Model now links risk characteristics and indicators



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Sources of risk

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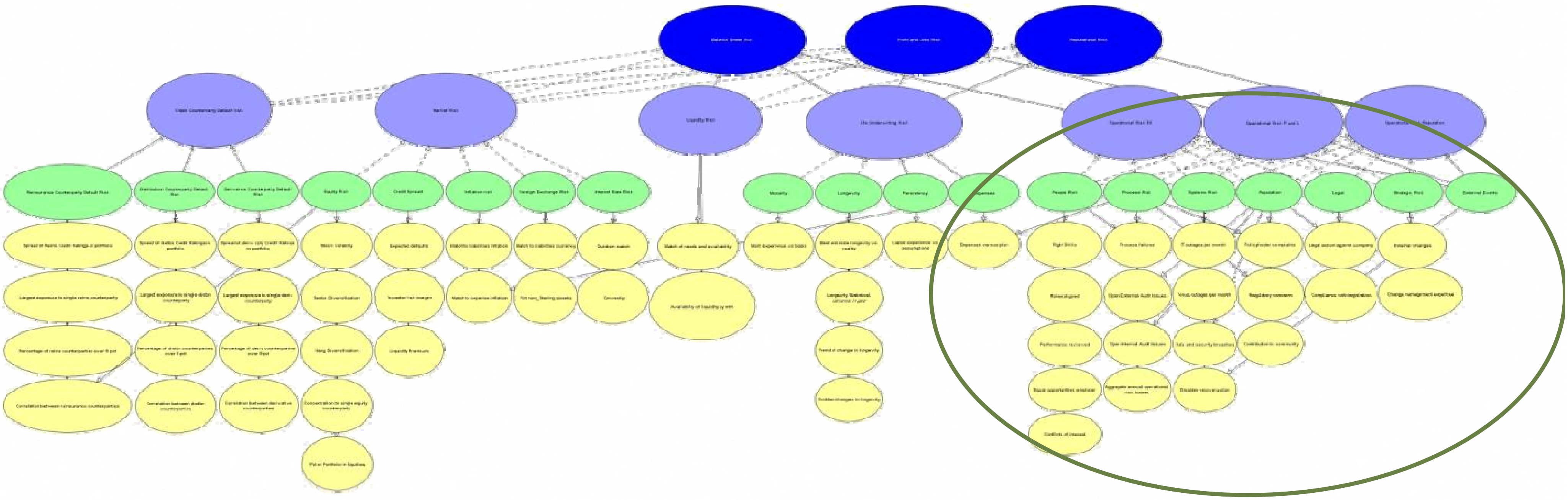
- Capture multiple influences



Op Risk in particular has indicators which link to more than one risk characteristic

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Setting Appetite

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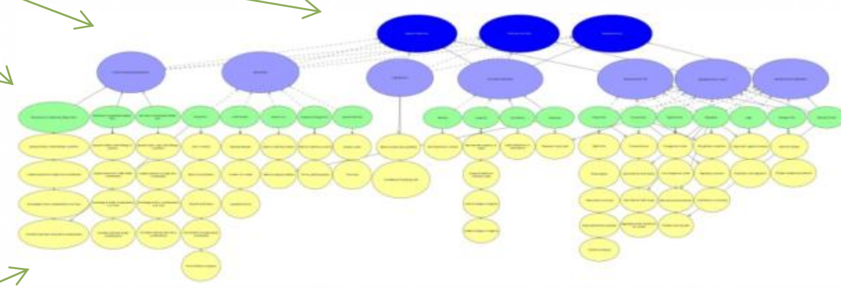
- Use propagation properties of Bayesian Networks

Setting an outcome here...



...tells us what the states ought to be here

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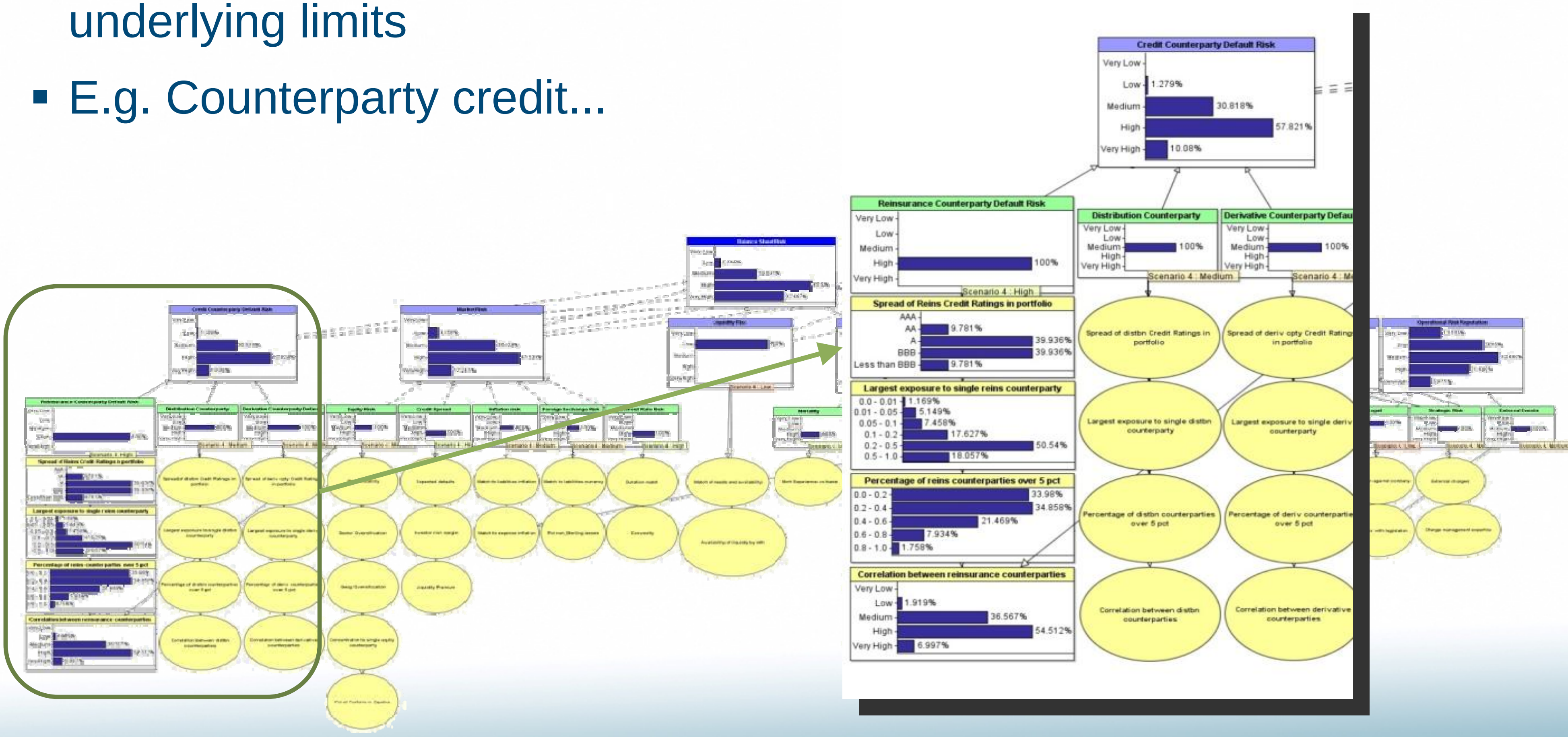
Propagating evidence

- Setting desired appetite level translates into information about underlying limits
- E.g. Counterparty credit...



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Monitoring

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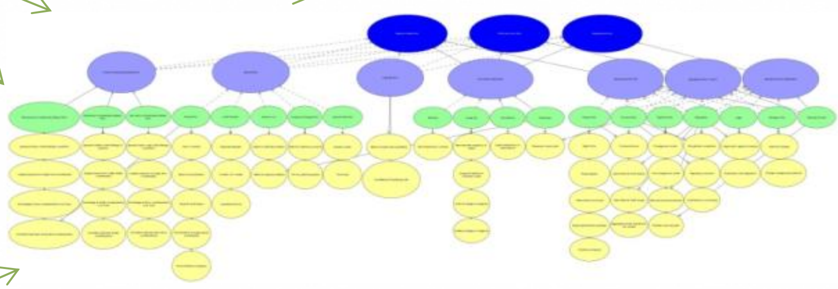
- Use propagation properties of Bayesian Networks

...gives us an estimate of risk level here



Entering observed values here...

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Monitoring risk levels

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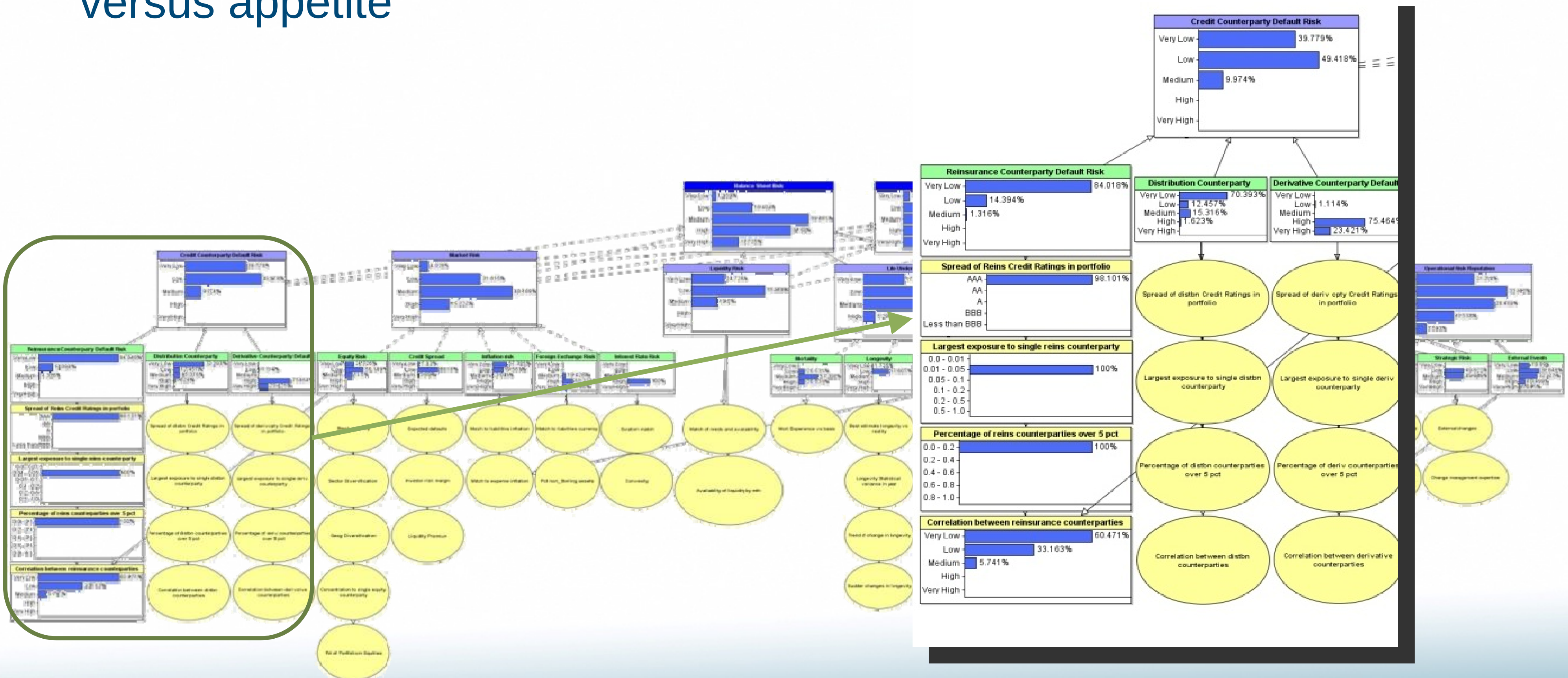
- Entering actual indicator values gives information about risk levels versus appetite



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Risk Appetite

- Proposed approach:
  - Embraces systems approach
  - Is scalable from small/simple to large/complex
  - Can apply to any type of firm
  - Reacts naturally to emerging information
  - Provides a basis for setting AND monitoring limits
  - Can make use of expert knowledge until data available
  - Retains a form of use and interest to business people
  - Can be explained easily

Other Applications

- Operational Risk
  - Business experts describe risk scenarios
  - Cognitive mapping analysis to remove bias and identify key features
  - Propose candidate model in Bayesian Network
  - Refine and parameterise using expert judgement and management info
  - Integrate scenarios with common factors
- Model remains in business language throughout
- Transparently combines financial and non-financial risk appetite
- A tool for:
  - ***Business*** to monitor risk levels and form business case for change
  - ***Risk management*** to assess risk interactions at business unit and enterprise level
  - ***Financial modellers*** to assess operational risk capital

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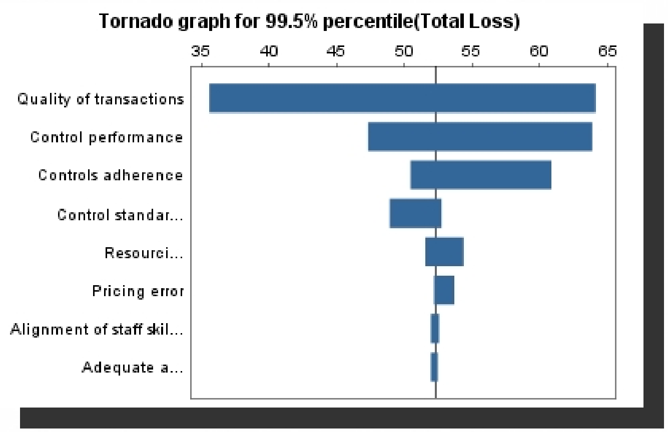
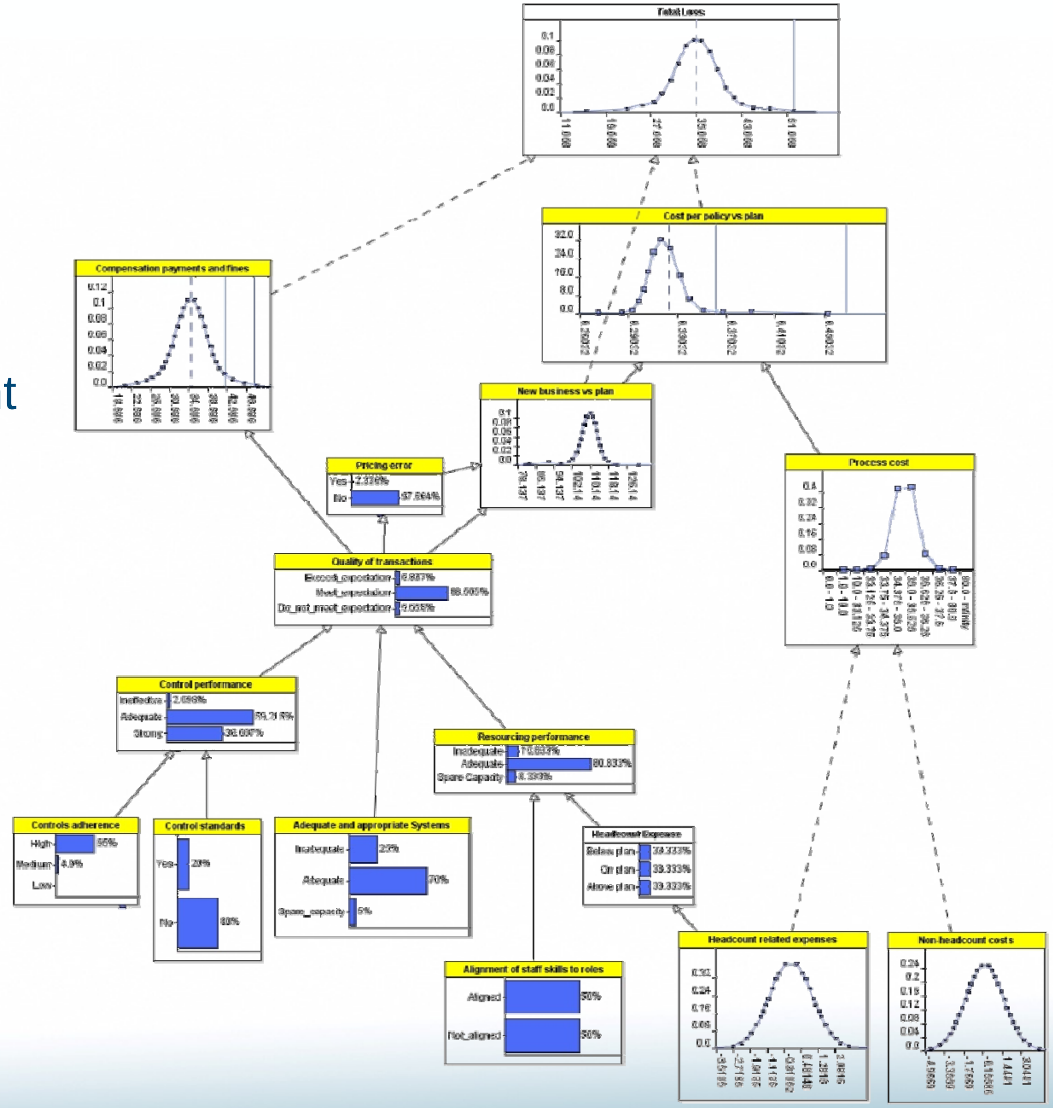
Example

- Operational Risk
  - Transaction error scenario
  - Elicit key drivers from experts
  - Parameterise from MI and judgement
  - Explore sensitivities





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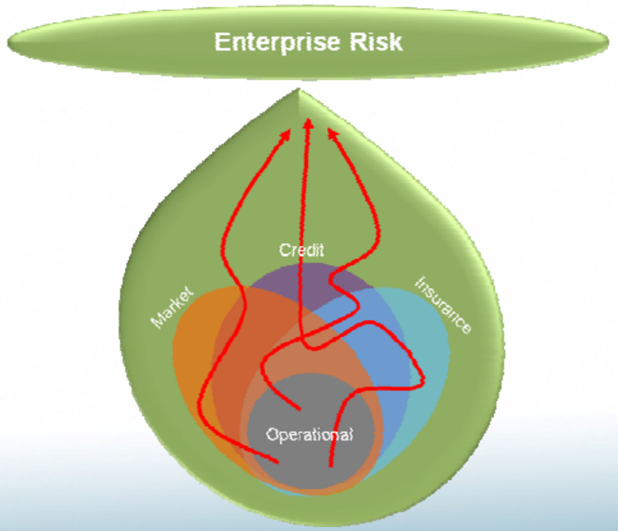
What Risk Really Looks Like

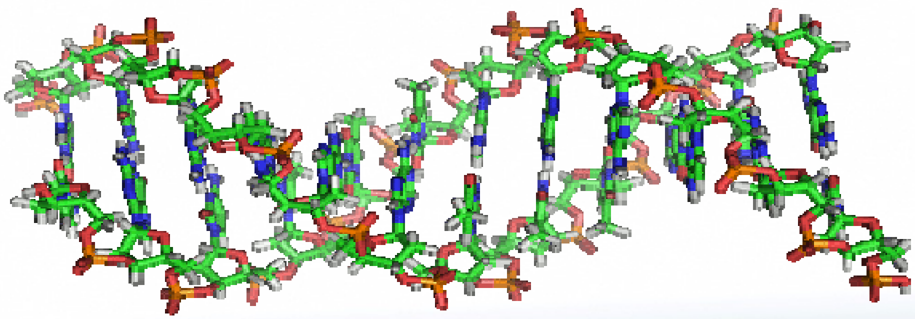
- People confuse "characteristics" with the risk itself
- Natural tendency to look at risk by "summing the parts" is encouraged by approaches to modelling and regulation of solvency capital

- Real risks have multiple characteristics
- They combine to produce "new" outcomes
- Need to understand the forces driving these dynamics



Evolutionary Forces

- Risks have a unique sequence, very much like a DNA
- Collective risk systems evolve and co-evolve
- The path-dependency is an important aspect of a risk
- A risk's evolutionary progression can be analysed
- Predictions made about how risks might develop
- It is an efficient way to classify and manage risks



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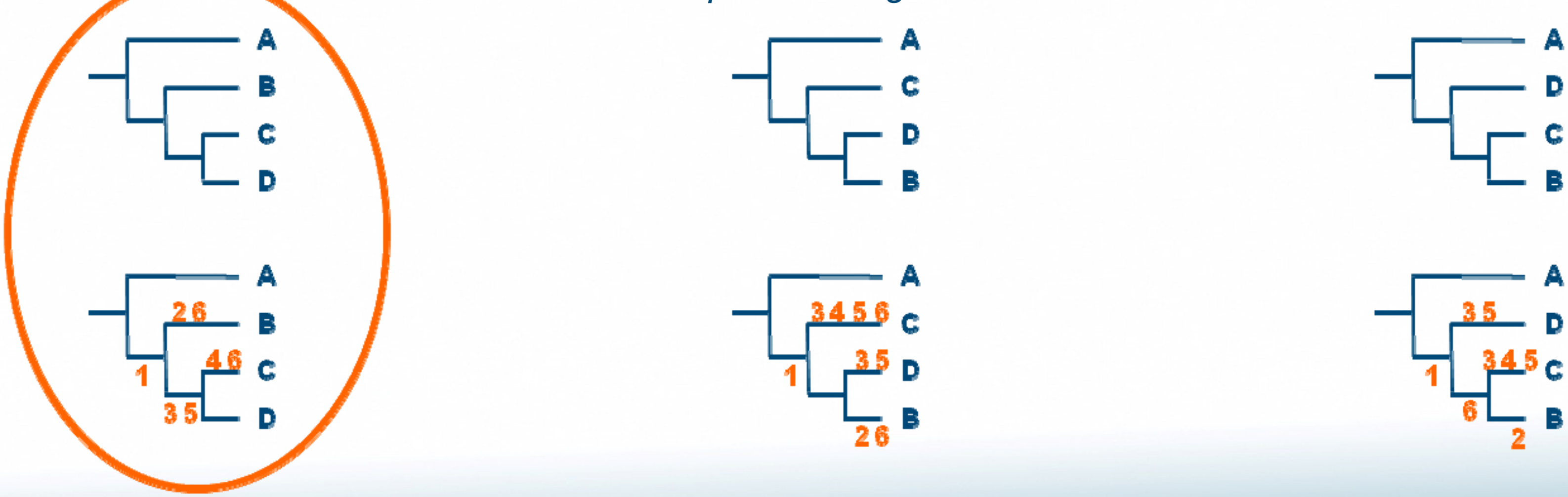
Maximum Parsimony

Taxa	1	2	3	4	5	6
A	N	N	N	N	N	N
B	Y	Y	N	N	N	Y
C	Y	N	Y	Y	Y	Y
D	Y	N	Y	N	Y	N

Three possible organisations



Most parsimonious solution

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Data preparation

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- Rows as risks or scenarios
- Columns as the corresponding risk characteristic labels
- '1' represents characteristic present in the risk

Risk ID	Risk	1.1 Portfolio risk selection	1.2 Portfolio Management	1.3 Claims management	1.4 Technical Reserving	1.5 Reinsurance arrangements
1	Economic Downturn.			1		
2	Failure to deliver the required scale and breadth of improvement plan benefits leading to under delivery of projected 2011 UW result.		1			
3	Business does not achieve planned growth.					
4	ABC Integration / alignment.					
5	Loss of key intermediary / corporate account through failure of intermediary or transfer of business to competitor.					
6	Non-compliance with regulatory requirements, including subsidiaries.					
7	Inadequate Data Privacy procedures.					
8	Risk of adverse development of Prior Year claims on X Book.					
9	Repeat of catastrophic weather events.	1	1		1	
10	Implementation of Periodic Payment Orders.	1	1			
11	Failure of Software House.					
12	Immature capability re direct and on-line channel.					
13	XXX Insurance S&P downgrade.					
14	Outcome of test Achats by ECJ – EU gender directive decision.					

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Step 1 – Produce an initial tree

- Produce an approx initial tree using min-mini or close neighbour algorithm
- Typically the algorithm will generate a number of trees equally as valid for representing the data (although these trees are all likely to be quite similar)
- It is necessary to condense these trees into a single tree for final analysis.
  - e.g. use the ‘consense’ program in the PHYLIP software package

Step 2 – Identify groups of highly related risks

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- The next step is to identify highly related risk groups (e.g. using CTree)
- The aim here is to create groups of related risks that share a common ancestor on which a more accurate algorithm can be applied
- Also these clusters can be used as a guide to isolating groups to root the tree
- The clusters should be checked against the tree produced in step 1 to ensure that they are sensible

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Step 3 – Apply exact algorithms to groups of highly related risks

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- Apply the max-mini branch and bound algorithm to each of these groups of highly related risks.
- This will give confidence that the evolutionary history of each of these groups is being represented as accurately as possible.

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Step 4 – Combine set of solutions for each group of highly related risks

- It is likely that there is still more than one ‘best’ evolutionary tree for each set of highly related risks.
- For further analysis combine these trees using ‘consense’.
- Each tree for each group of highly related risks should then be rooted as in the rooted tree produced by step 2.

Step 5 – Rejoin groups into a final tree

- Each group of highly related risks should be joined together to produce a final single tree.
- In order to be able best graphically represent the tree use Mesquite program.
- This also allows on-the-tree display of the evolutionary characteristic. This is important for interpretation.

Step 6 – Verify Evolutionary Tree

- The best way to validate the tree is to check if the results are sensible with someone who knows the business.
- However a couple of useful metrics do exist:
  - the consistency index, which is a measure of how well the character data fits the evolutionary tree;

$$Consistency\ index = 0.90 - 0.022 * N_R + 0.000213 * (N_R)^2$$

  - and the retention index, which is a measure of common ancestry in an evolutionary tree (>0.5 is good).

Classifying risks

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- Are there any characters which are completely absent or present in each group?
- Which characters are mostly present or absent?
- How do these compare to other groups?
- Are there unexpected similarities in characters in what appear to be distantly related risks?
- Do some groups have a larger number of characteristics than others?
- Are some groups more diverse than others?
- Are some groups much larger than others?

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Risk Characteristics for this example

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Risk Characteristic	Code
1.1 Portfolio risk selection	1
1.2 Portfolio Management	2
1.3 Claims management	3
1.4 Technical Reserving	4
1.5 Reinsurance arrangements	5
1.6 Longevity risk (Pension)	6
1.7 Pricing	7
2.1 Reinsurance Credit Risk	8
2.2 Insurance products credit risk+A23	9
2.3 Insurance operations credit risk	10
2.4 Invested assets credit risk	11
3.1 Asset and liability matching	12
3.2 Investment default	13
3.3 Currency risk	14
3.4 Basis risk	15
3.5 Property price depreciation	16
3.6 Equity risk	17
3.7 Interest rate risk	18
3.8 Commodity risk	19
3.9 Spread risk	20
4.1 Assets liquidity	21
4.2 Funding liquidity	22
4.3 Liability liquidity	23
4.4 FX liquidity	24
4.5 Intra-day liquidity	25
5.01 Internal fraud / Unauthorised Transactions	26
5.02 Internal fraud / Theft and Fraud	27
5.03 External Fraud / Theft and Fraud	28
5.04 External Fraud / System Security	29

5.05 Employment Practices / Employee Relations	30
5.06 Employment Practices / Safe Environment	31
5.07 Employment Practices / Diversity & Discrim.	32
5.08 Improper Business or Market Practices	33
5.09 Published Financial Statements	34
5.10 Advisory activities	35
5.11 Damage to Physical Assets	36
5.12 Bus disruption & sys failures / Systems	37
5.13 Transaction Capture & Maintenance	38
5.14 Monitoring & Reporting	39
5.15 Customer Intake and Documentation	40
5.16 Customer & Client Account Management	41
5.17 Trade counterparties	42
5.18 Vendors & Suppliers	43
5.19 Compliance with existing regulation	44
5.20 Increase in regulatory costs	45
5.21 Failure to implement Solvency II	46
5.22 Cross sector funding FSCF	47
5.23 Product Flaws	48
5.24 Expenses overruns	49
6.1 Regulators	50
6.2 Corporate responsibility	51
6.3 Investors / JV Partners	52
6.4 Media	53
7.1 Legal, Public Affairs & Regulatory	54
7.2 Macro-Economic	55
7.3 Changing Claims Patterns	56
8.1 Internal	57
8.2 External	58
8.3 General	59

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Interpreting Evolutionary Properties

- Look at tree shape
  - areas of cascading bifurcation are likely areas for more evolution and therefore emerging risks
- Identify branches that have the most characters/adaptation
  - They are more likely to adapt again
- Find characters that evolve most frequently
  - Is there a character or pattern that is responsible?
- Are any risks/branches losing characters, ask why?
  - Risks should generally increase in complexity
- Are there any characters gained in sequence/coevolution?
  - Understand this pattern as a possible clue to new risks

Case study – Multinational insurer country data

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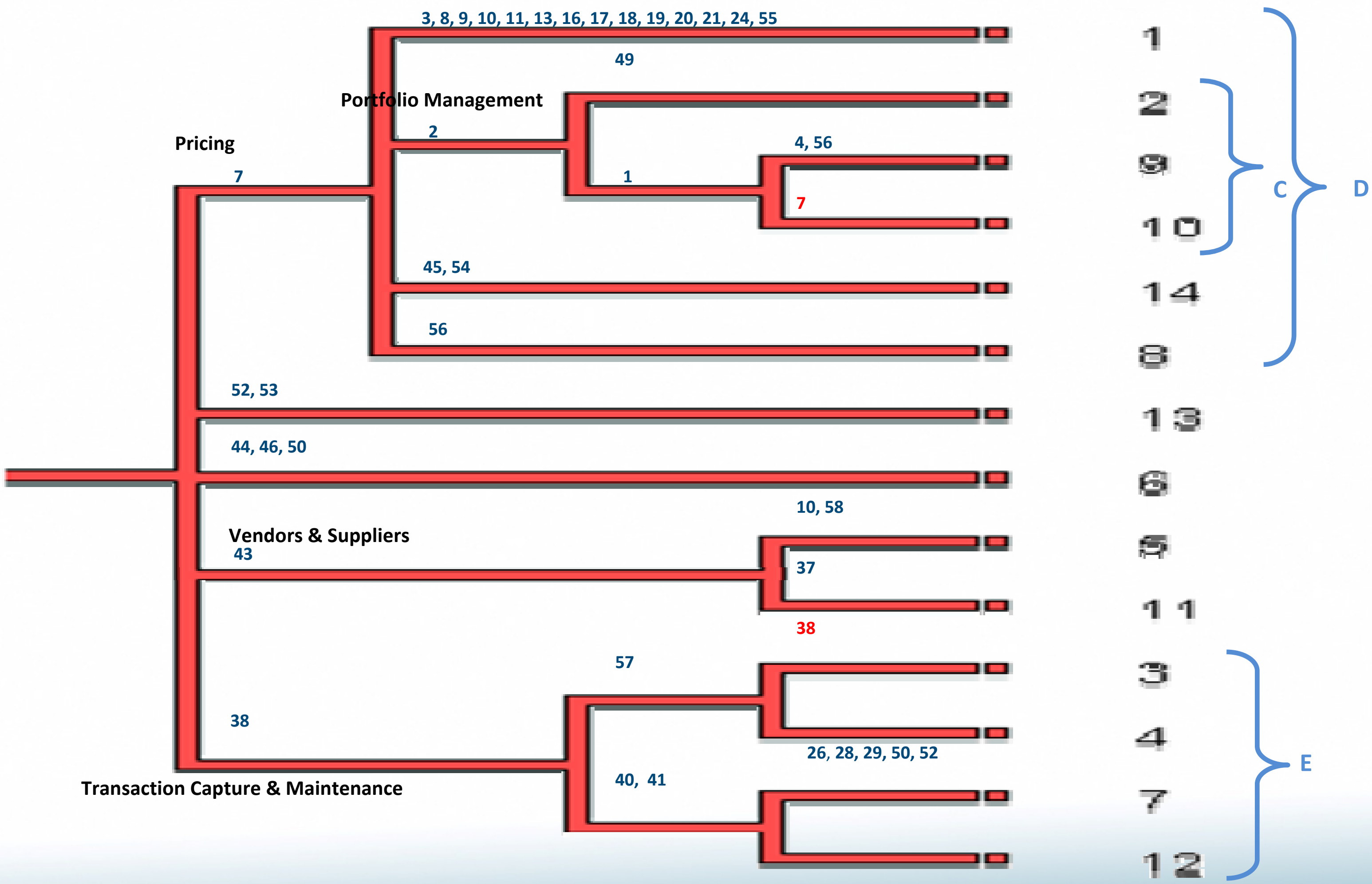

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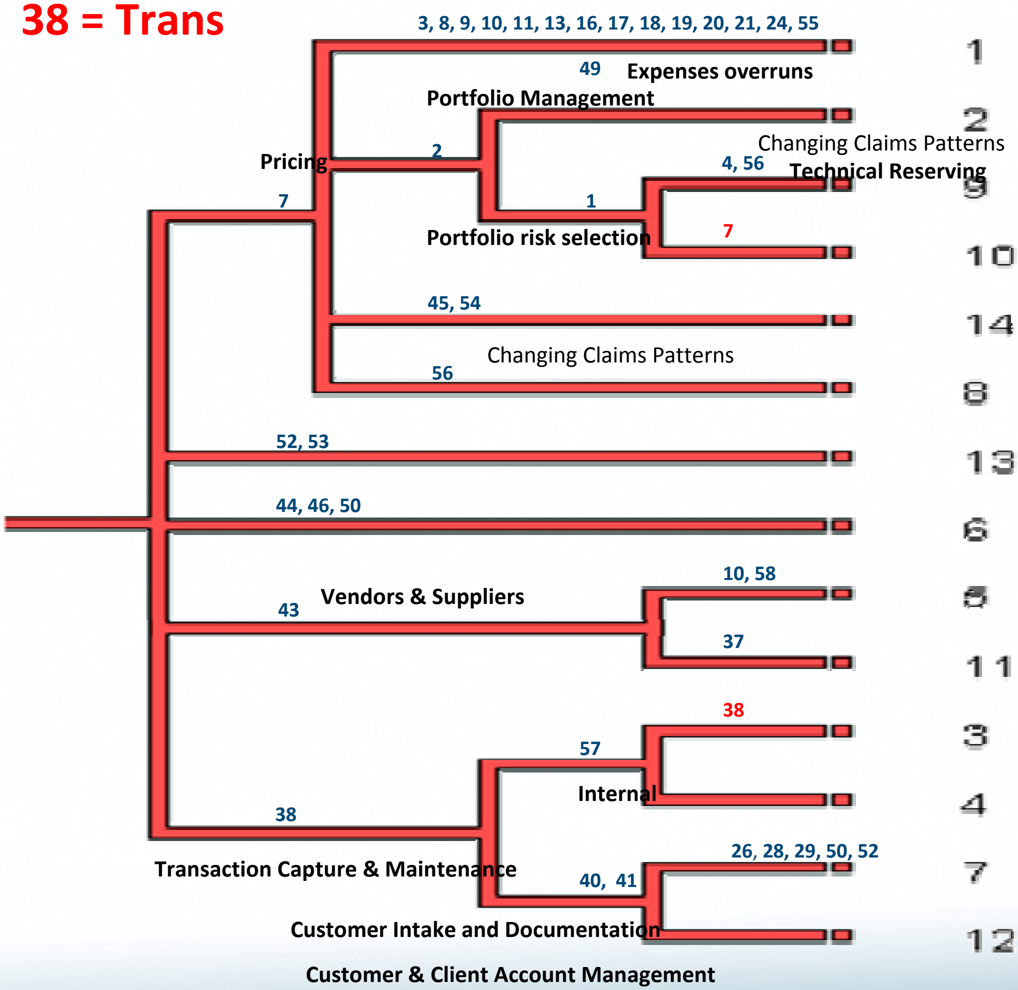
Country analysis

7 = Pricing
38 = Trans



Economic Downturn
Under delivery of projected UW result
Repeat of catastrophic weather events
Implementation Periodic Payments
Outcome - EU gender directive
Prior Year claims on X Book

Bus doesn't achieve planned growth
ABC integration / alignment
Inadequate Data Privacy procedures
Immature capability re on-line channel

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Questions for Country example

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- ‘Economic downturn’, indeed is complex and could easily have another character attach and also could split into something else e.g. Euro crisis, Housing crisis, Japanese earthquake
- Risk 7 is branching and has many characters so maybe new risk between ‘Inadequate Data Privacy Procedures’ & ‘Immature Capability re On-line Channel’ e.g. On-line breaches of privacy (Sony play station)
- Pricing character no ‘7’ (next slide for evidence) is one of the most changeable characters across all the countries and is prevalent here – one for management.

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Characters frequency v parsimony steps

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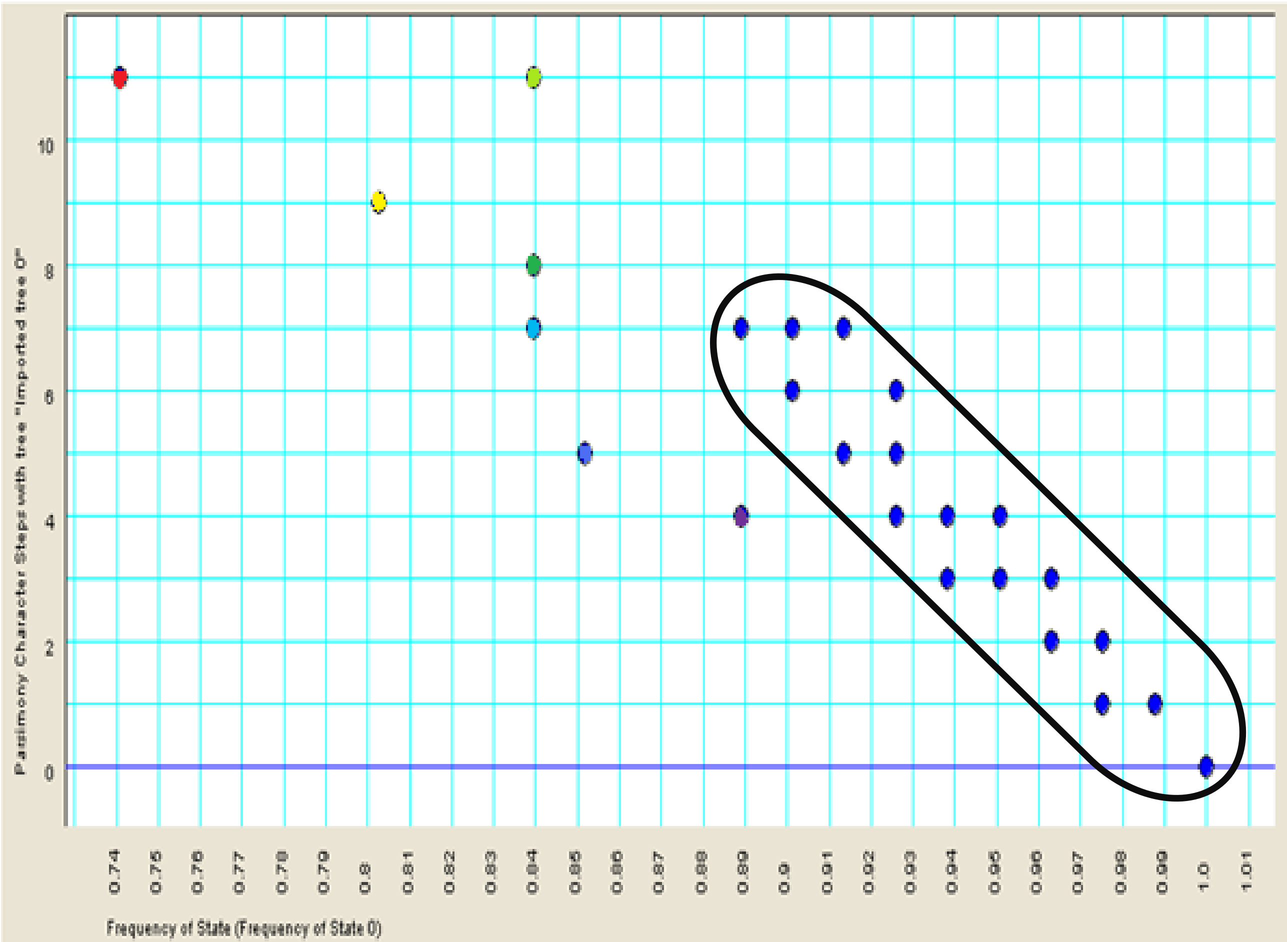

- Pricing (7)
- Portfolio Management (2), Claims management (3)
- Changing Claims Patterns (56)
- Legal, Public Affairs & Regulatory (54), Transaction Capture & Maintenance (38)
- Internal (57)
- Portfolio risk selection (1)
- Monitoring & Reporting

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Comparing trees

- Two countries both have pricing clades, both prominent
- Look at structure of the clades...different
  - Is one more logical than another?
  - Why might that be...is there a reason?
  - Why is character 5 missing (reinsurance provision)
- Character 54 is in both clades but why not 45 ‘Increase in regulatory costs’ in one country
- Evolutionary representation helps to surface questions for us to discuss
- Currently being used to facilitate emerging risk discussions and risk framework effectiveness

Compare Trees

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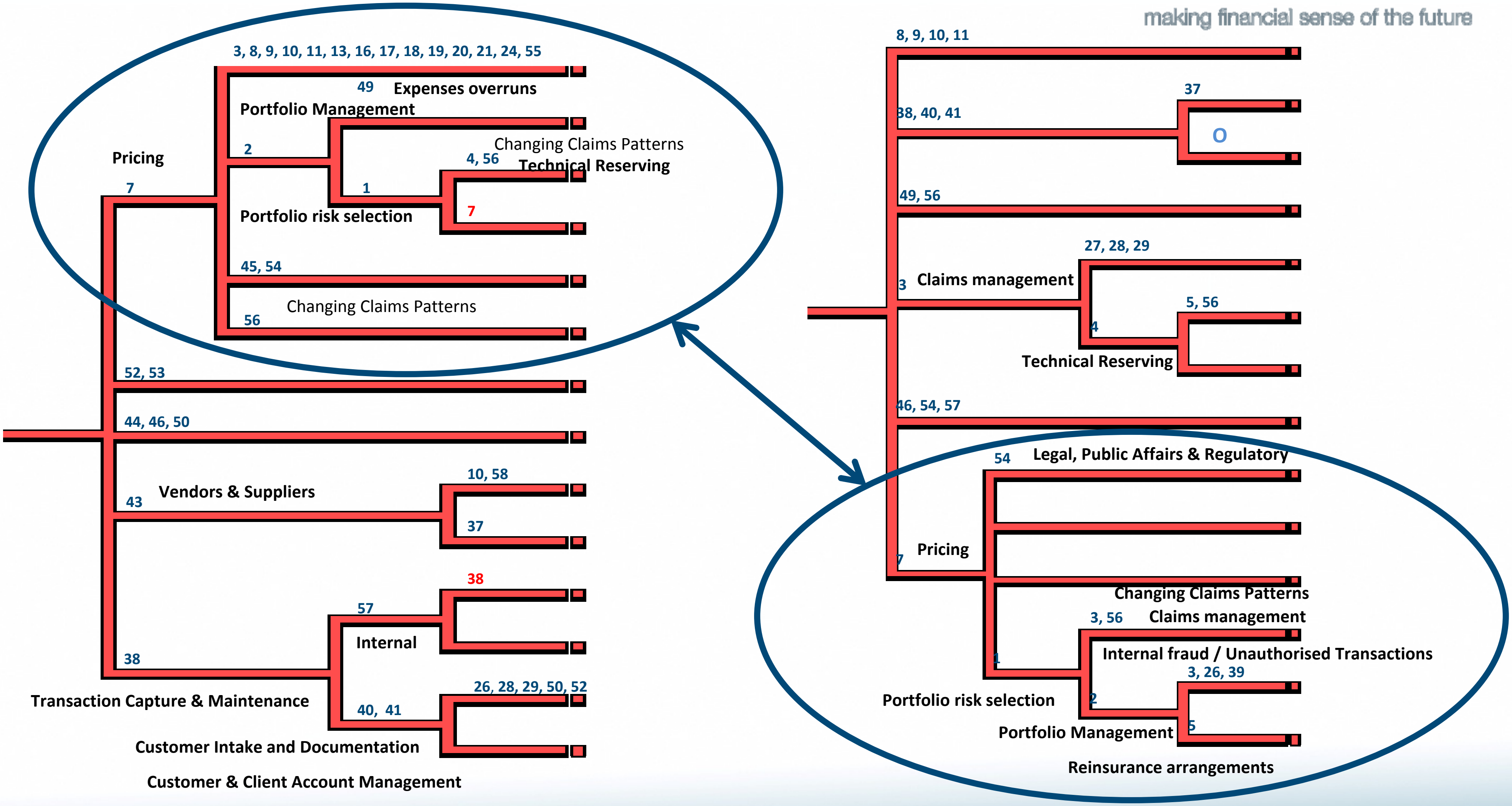

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Co-evolution? For instance:

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- E.g. Risk 7 ‘Inadequate Data Privacy procedures’, might gain a media character. Why?
  - Media (53) only evolves in presence of ‘Investors / JV Partners’ (52) so only risks that have ‘Investors / JV Partners’ (52) may gain ‘Media’ (53). Risk 7 has (52) but not (53)
- Risk 5 ‘Business does not achieve planned growth’ has ‘Insurance operations credit risk’ (10) and may gain Reinsurance Credit Risk (8), Insurance Products Credit Risk (9) and Invested Assets Credit Risk (11). Why?
  - Reinsurance Credit Risk (8), Insurance Products Credit Risk (9), Insurance operations credit risk (10) and Invested Assets Credit Risk (11) all evolve simultaneously in the two countries

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All countries added to one tree – same principles

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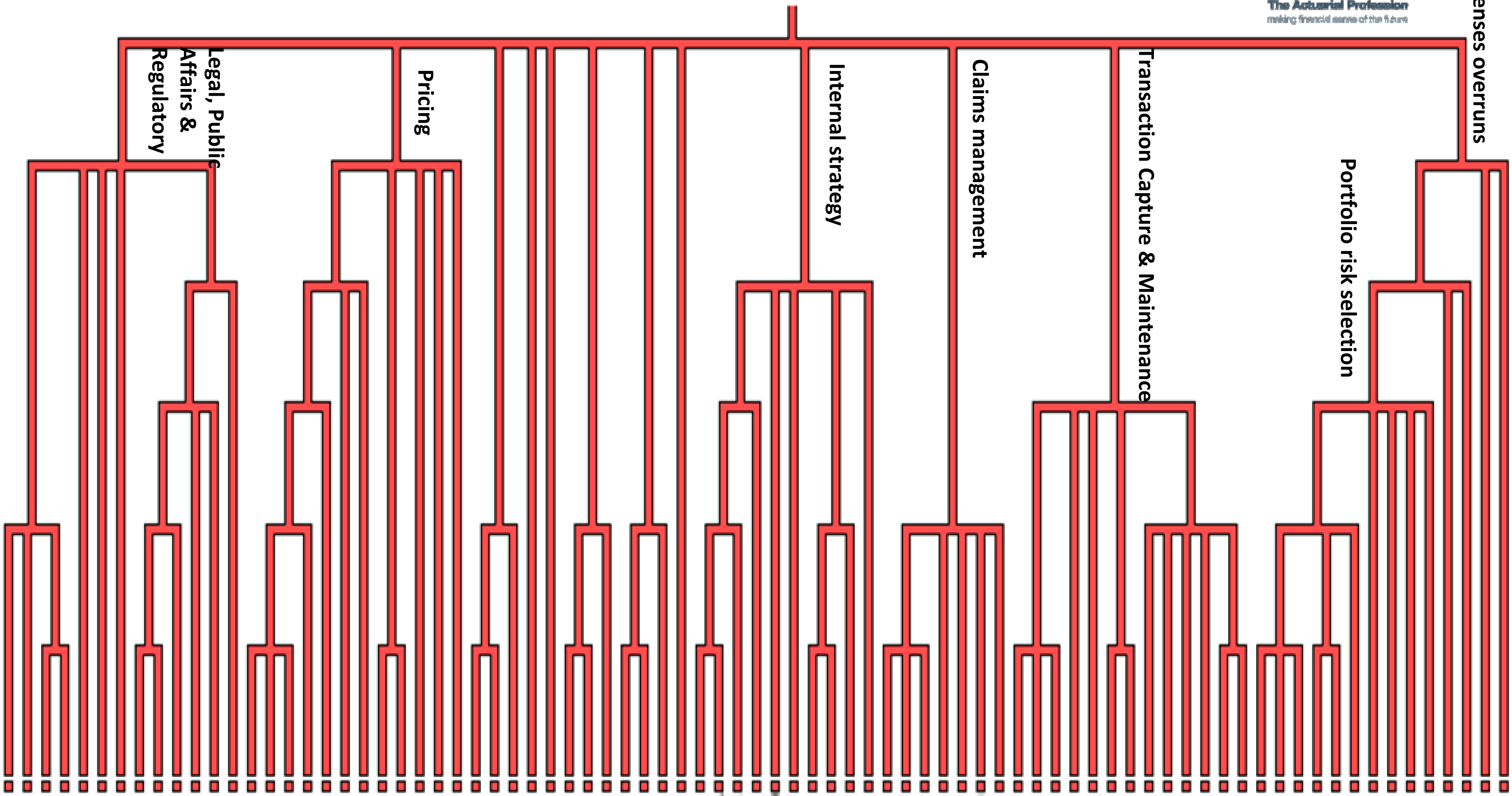

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General overview

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Key evolutionary character	Number of descendant risks	Important Clade
Expenses Overruns (49)	14	A
Transaction Capture & Maintenance (38)	13	B
Legal, Public Affairs & Regulatory (54)	13	Clade G
Portfolio Management (2)	12	Subclade of A
Pricing(7)	12	F
Internal (57)	7	D
Claims Management (3)	7	C
Claims Management (3)	7	Subclade of F
Portfolio Risk Selection (1)	6	Subclade of A

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Summary

- Modern business needs modern risk management
- Modern business is complex, non-linear and rapidly adaptive
- We can use concepts and tools from CAS to help
- Important concepts:
  - Holism
  - Non-linearity
  - Adaptation / evolution
  - Spotting patterns needs an open mind
  - Critical complexity
  - Give out signatures of trouble for us to spot
- Using the right tools is actually easier!

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Dare to think differently...

Discussion / Questions