The Actuarial Profession
making financial sense of the future

Risk and investment conference 2011 - Investing in risk
Neil Cantle, Milliman and Neil Allan, University of Bristol

Applications of complexity science

The Actuarial Profession
making financial sense of the future

Applications of complexity science

Introduction

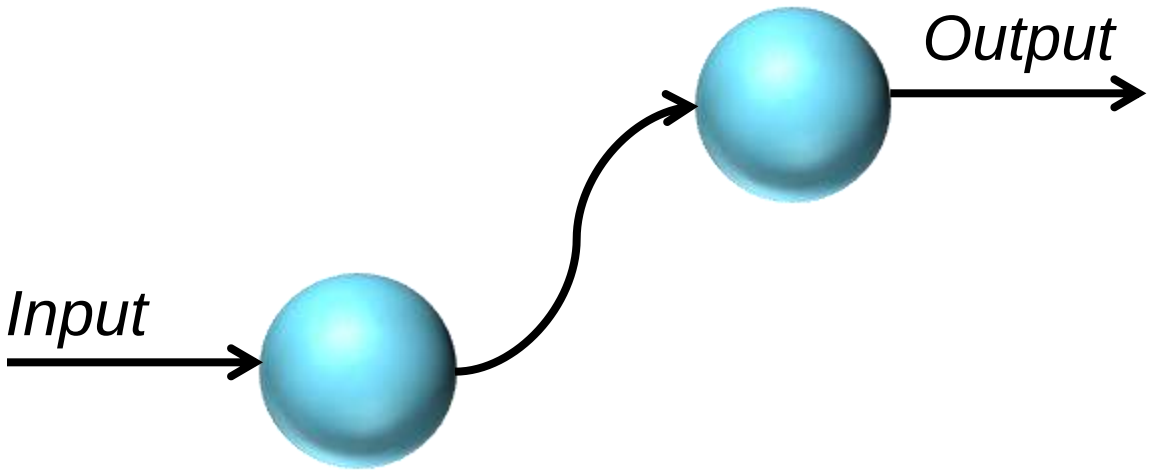
Starting Point

- 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

Systems Thinking

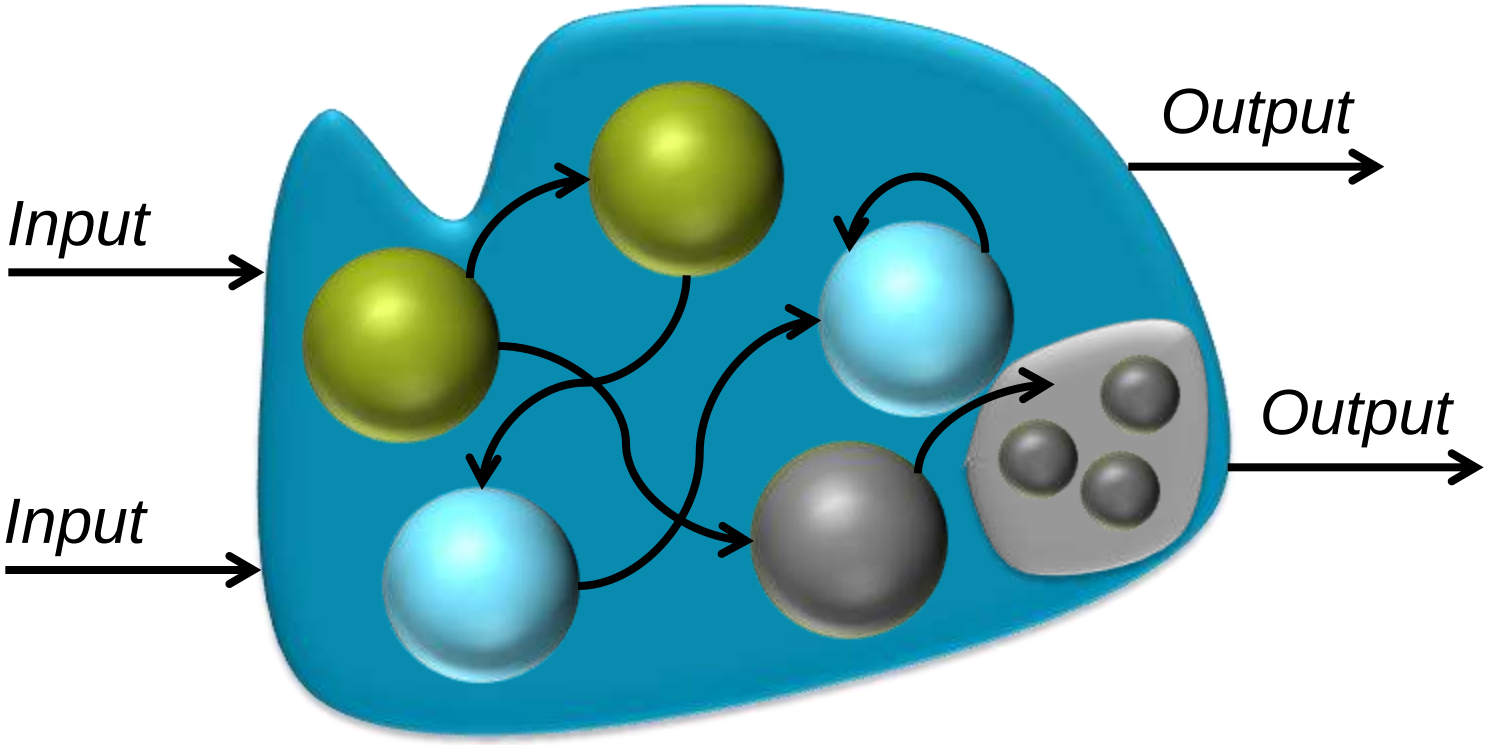
- Systems thinking is both a worldview that:
  - Problems cannot be addressed by reduction of the system
  - System behaviour is about interactions and relationships and
  - Emergent behaviour is a result of those interactions
- And a process or methodology
  - To understanding complex system behaviour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

Introduction to Systems



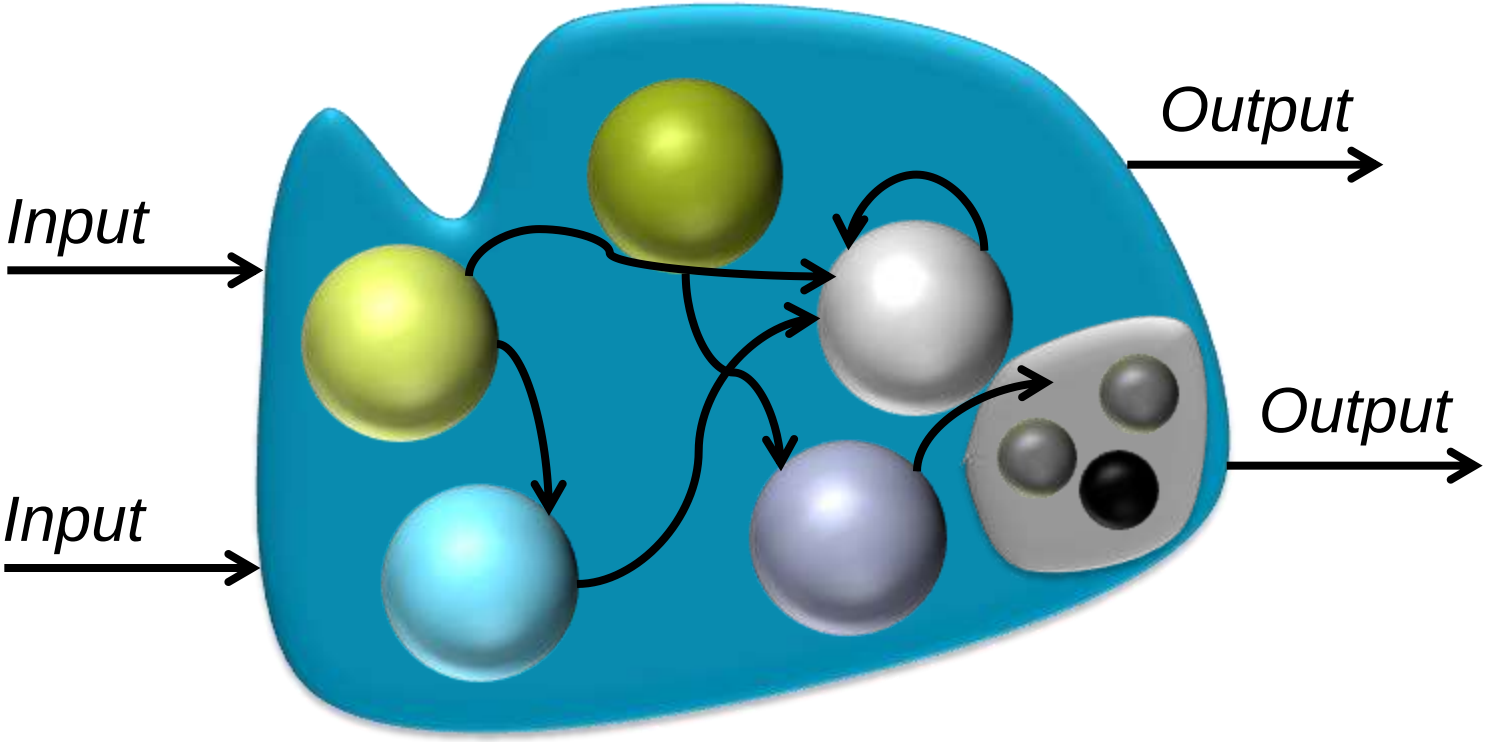
A set of components interconnected for a purpose

Introduction to Systems



Complex System – Feedback, subsystems, etc.

Introduction to Systems



Complex Adaptive System – Structure changes

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

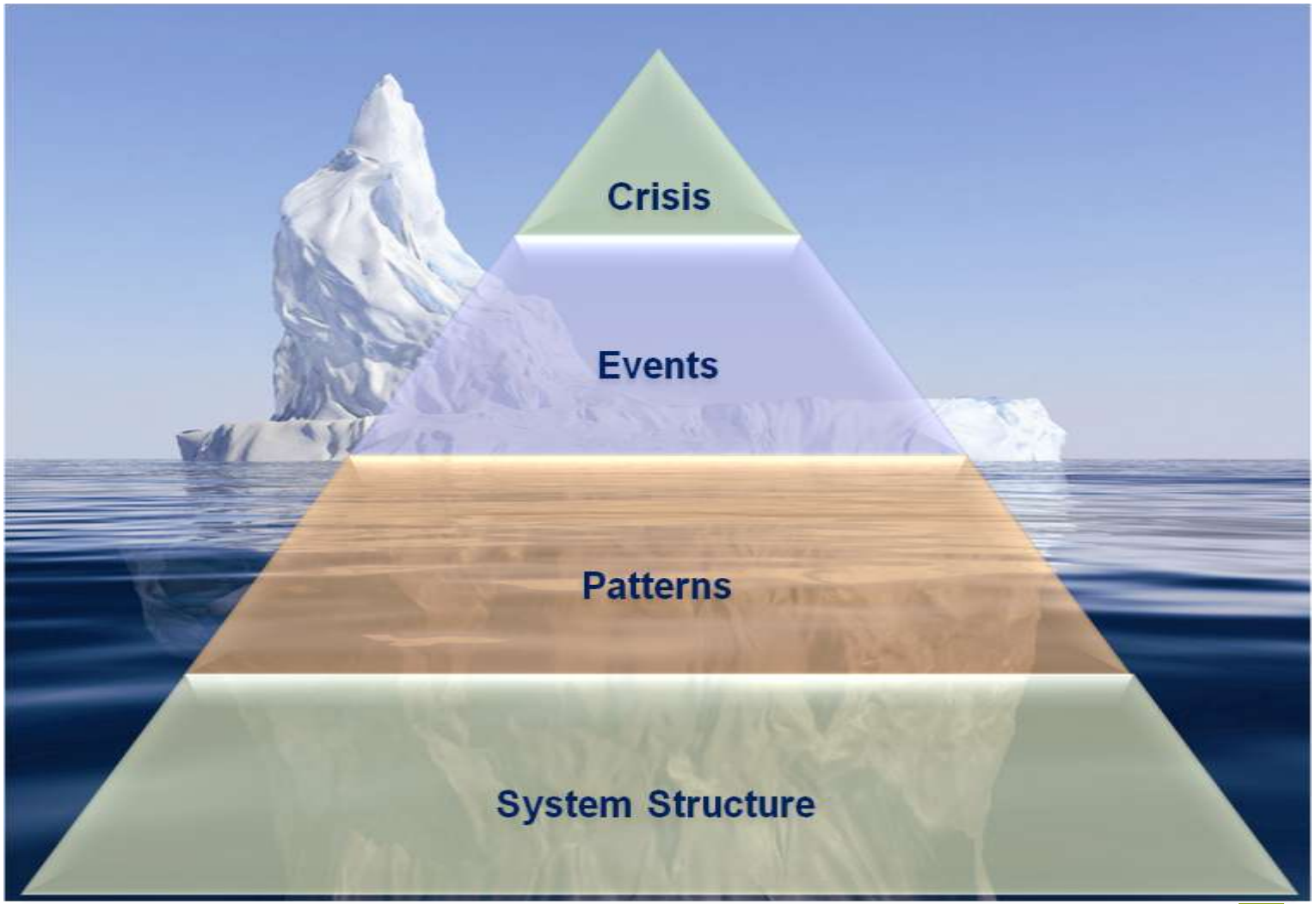
Level of Understanding

Symptoms

Causes

Sense-making

Understanding



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 a function of the past system performance

The Actuarial Profession
making financial sense of the future

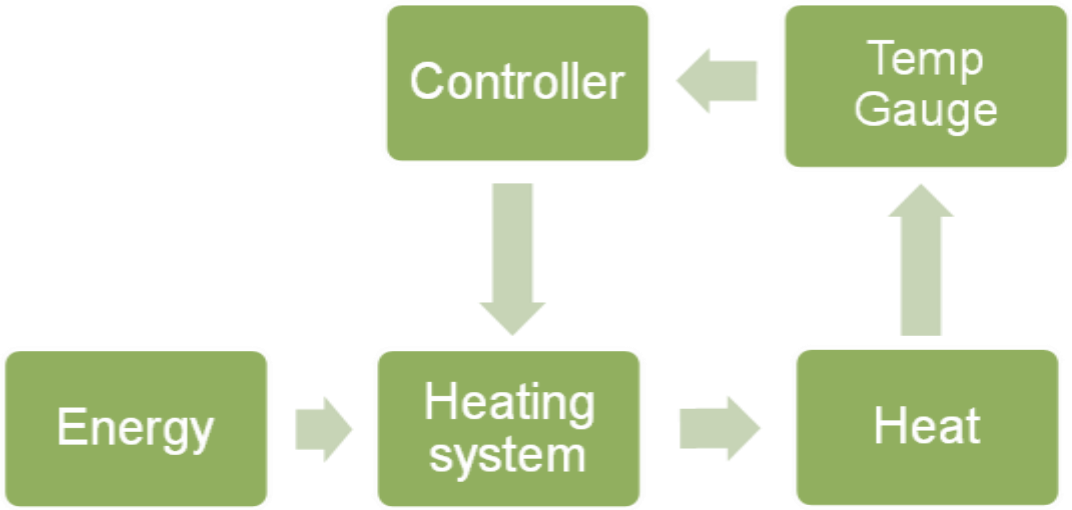
Applications of complexity science

Risk Appetite

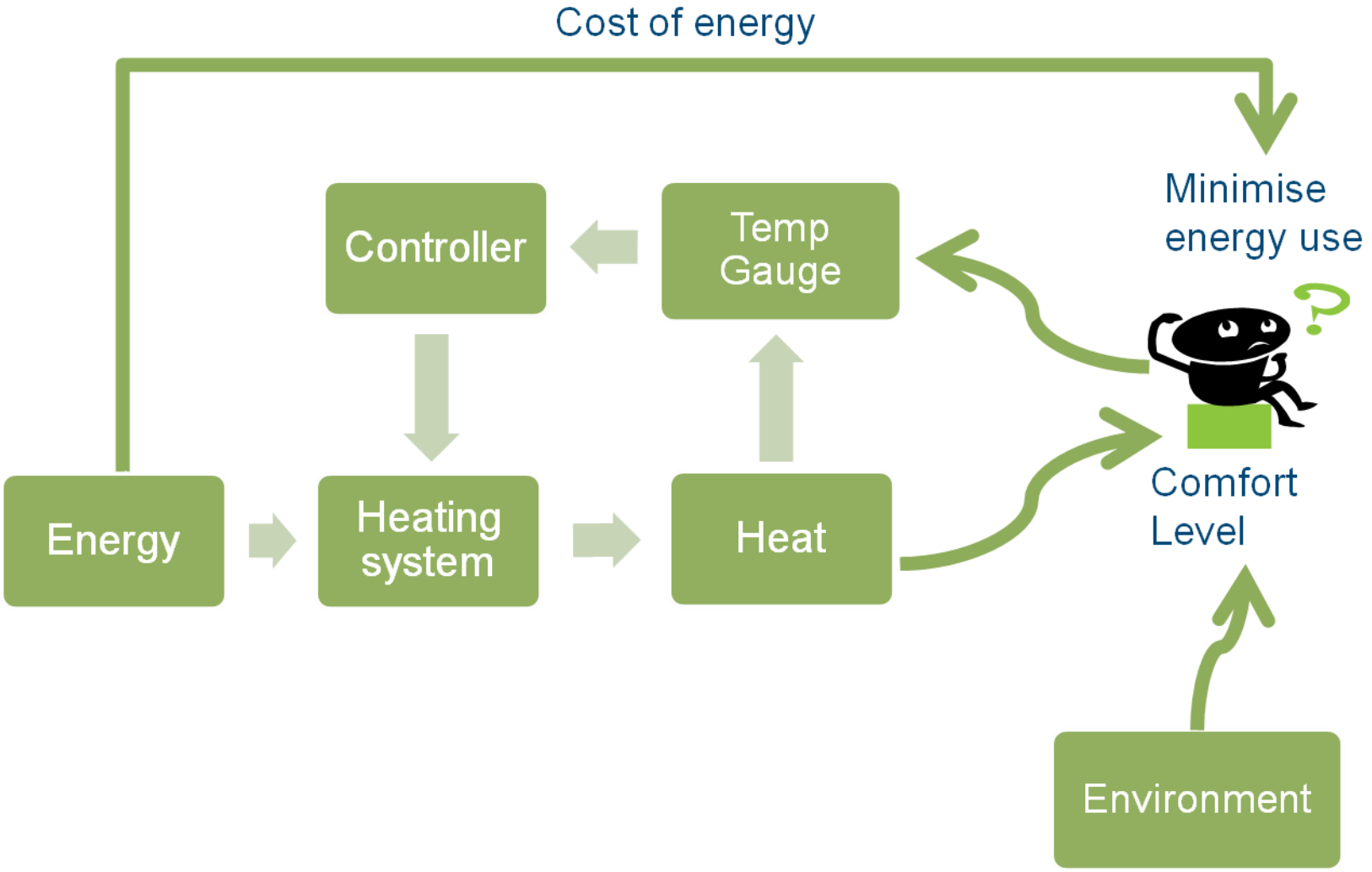
Risk Appetite

- **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)
- **Risk Appetite** = “our comfort and preference for accepting a series of interconnected uncertainties related to achieving our strategic goals”
- **Risk Limits** = operational restrictions intended to maintain performance within risk appetite

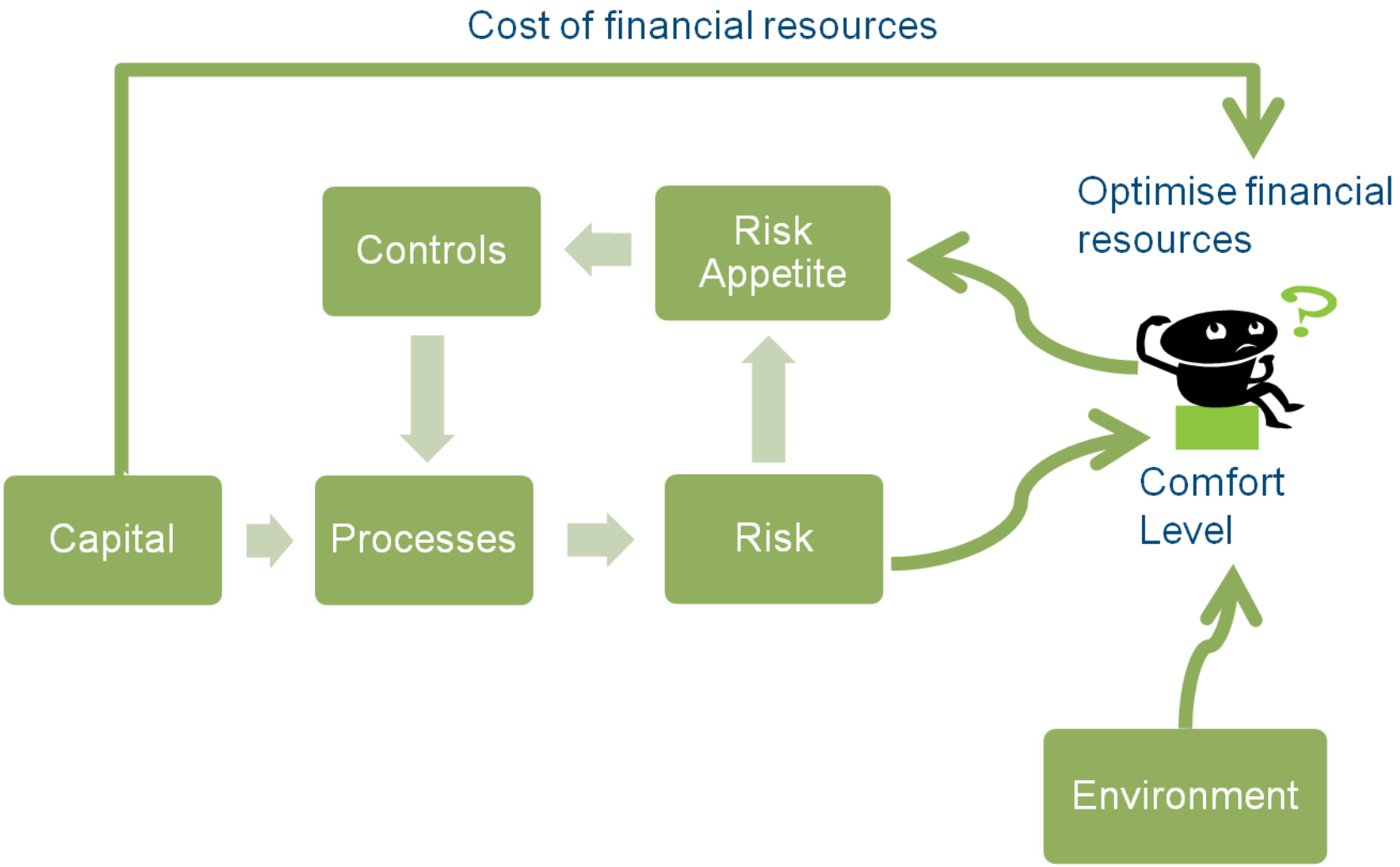
Idealised heating system



Real world heating system



Business as a heating system



From the top

- 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

From the top

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
- 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

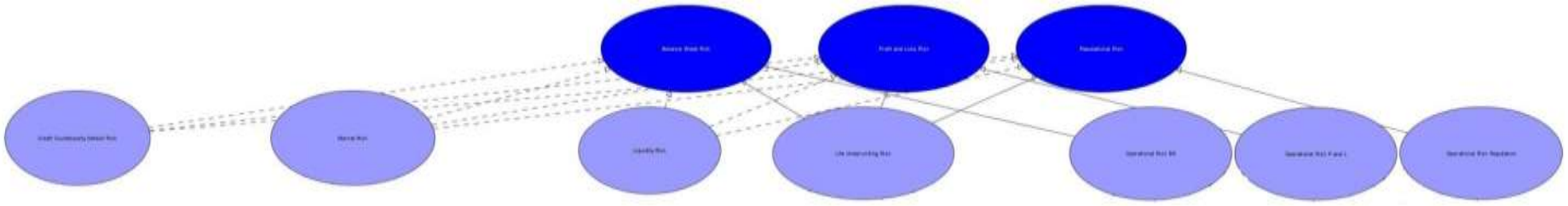
e.g. Equivalent to holding c138% of SCR

Sources of risk

- 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

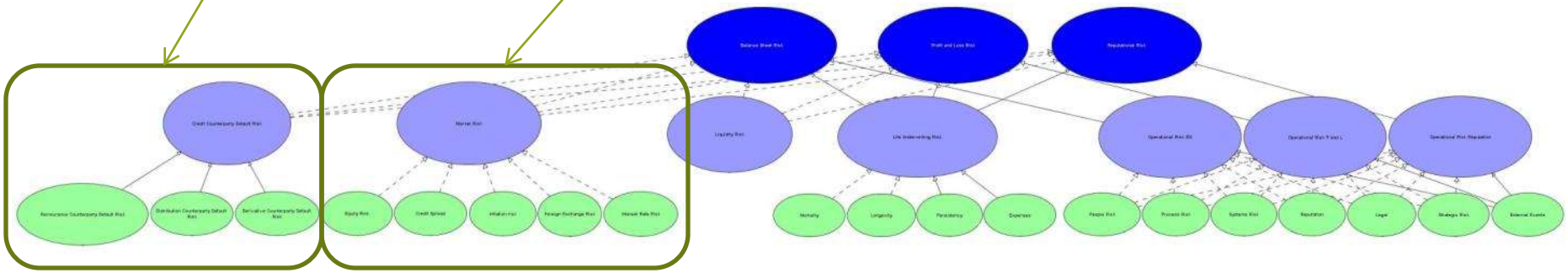
Can be "learned" if sufficient data available.



Sources of risk

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

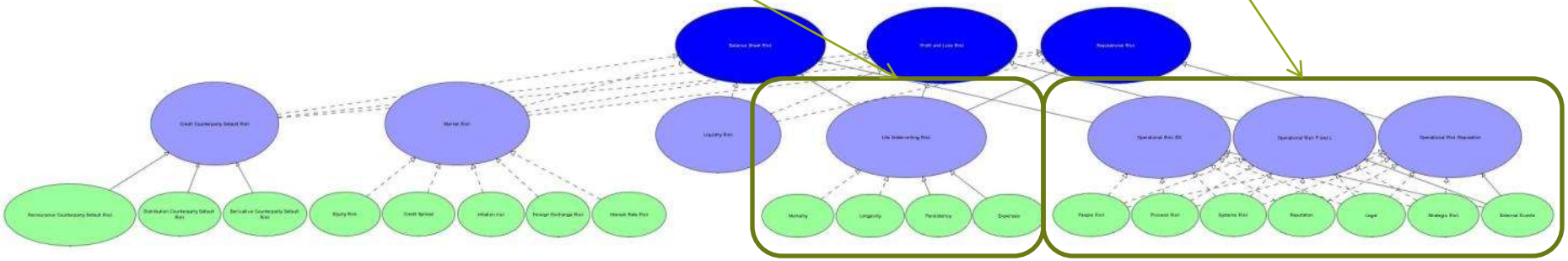
- Market:
  - Equity
  - Credit spread
  - Inflation
  - Foreign exchange
  - Interest



Sources of risk

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

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



Joining top to bottom

- 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

Identifying indicators

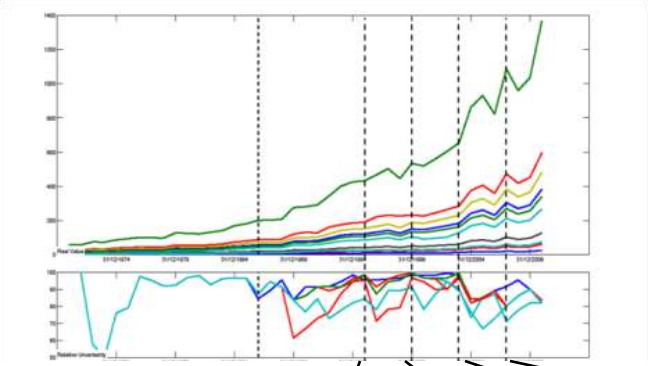
- Use a combination of cognitive and data-driven methods
- Leverage expert knowledge using cognitive mapping
  - Workshop with experts to describe risk dynamics
  - Note management actions/controls
  - Describe observable outcomes of drivers
  - Convert workshop discussion into cognitive map
  - Analyse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

Cognitive Maps

- 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

Checking indicators

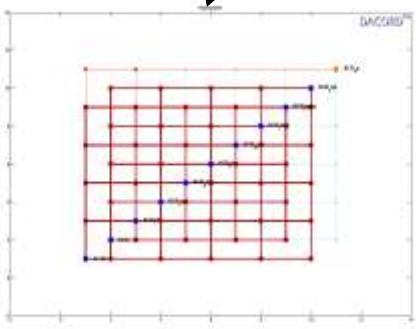


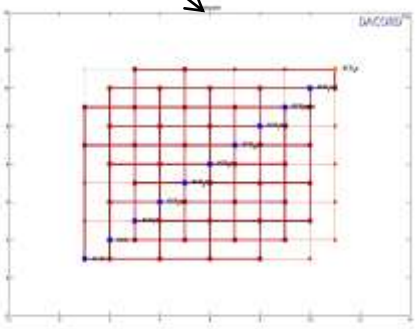
- If we have data, we can use information theory measures, such as mutual information, to determine relevance of indicators

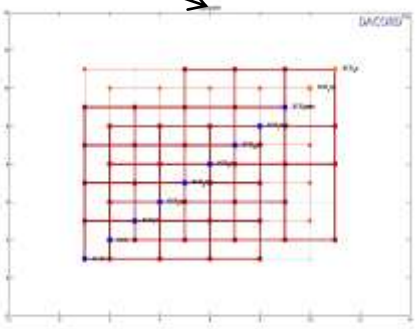
Produced by Milliman using:

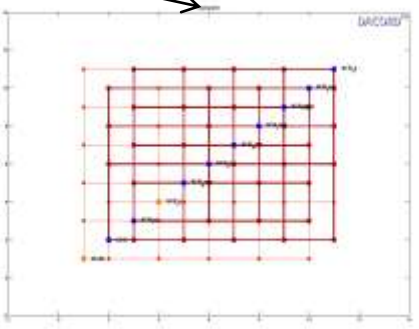
DACORD™

DRTS
www.drts.co.uk



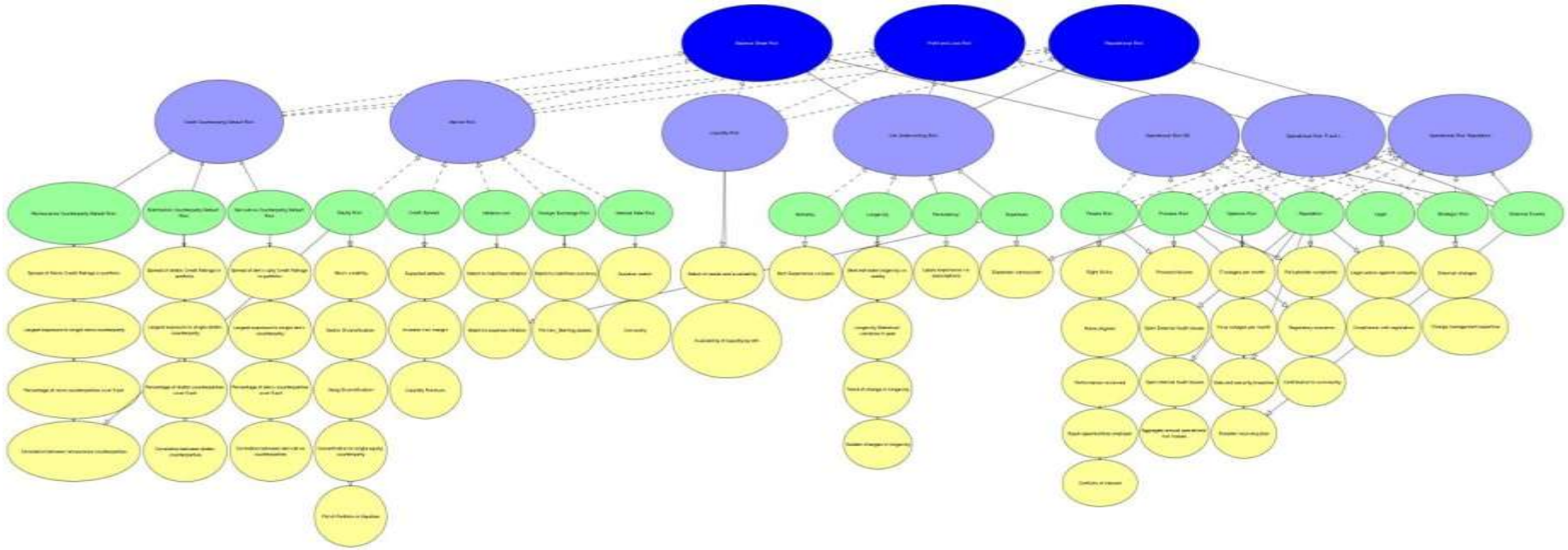






Sources of risk

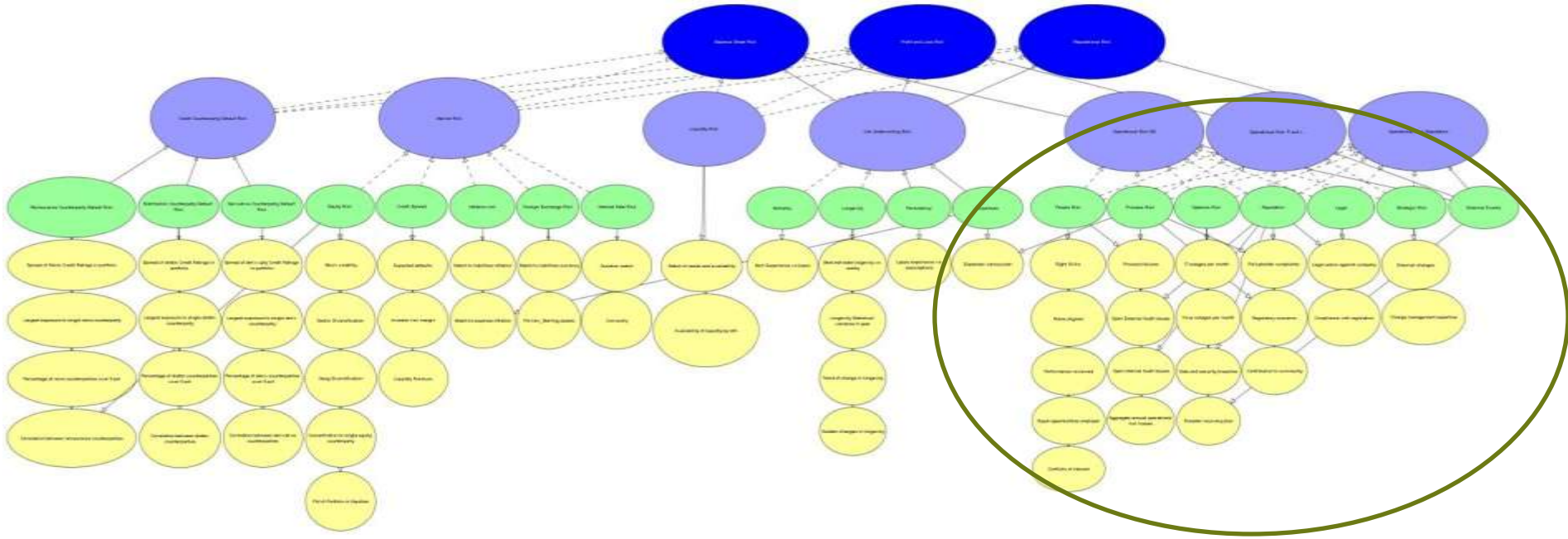
- Model now links risk characteristics and indicators



Implemented in AgenaRisk

Sources of risk

- Capture multiple influences



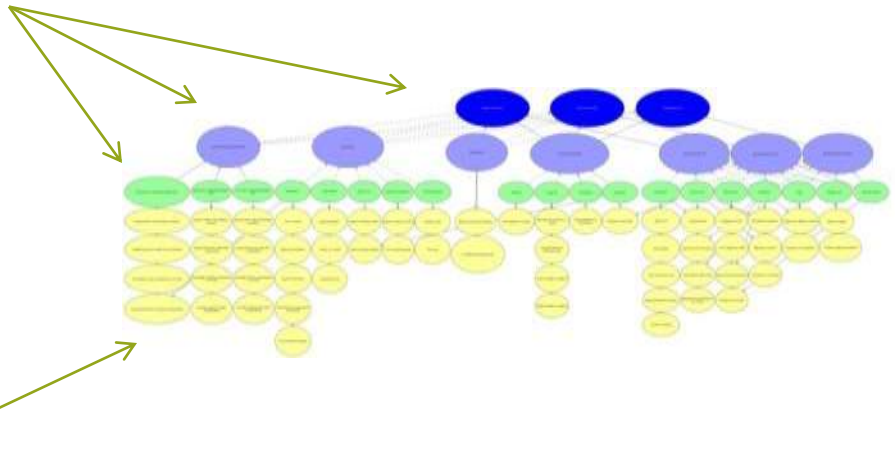
Op Risk in particular has indicators which link to more than one risk characteristic

Implemented in AgenaRisk

Setting Appetite

- Use propagation properties of Bayesian Networks

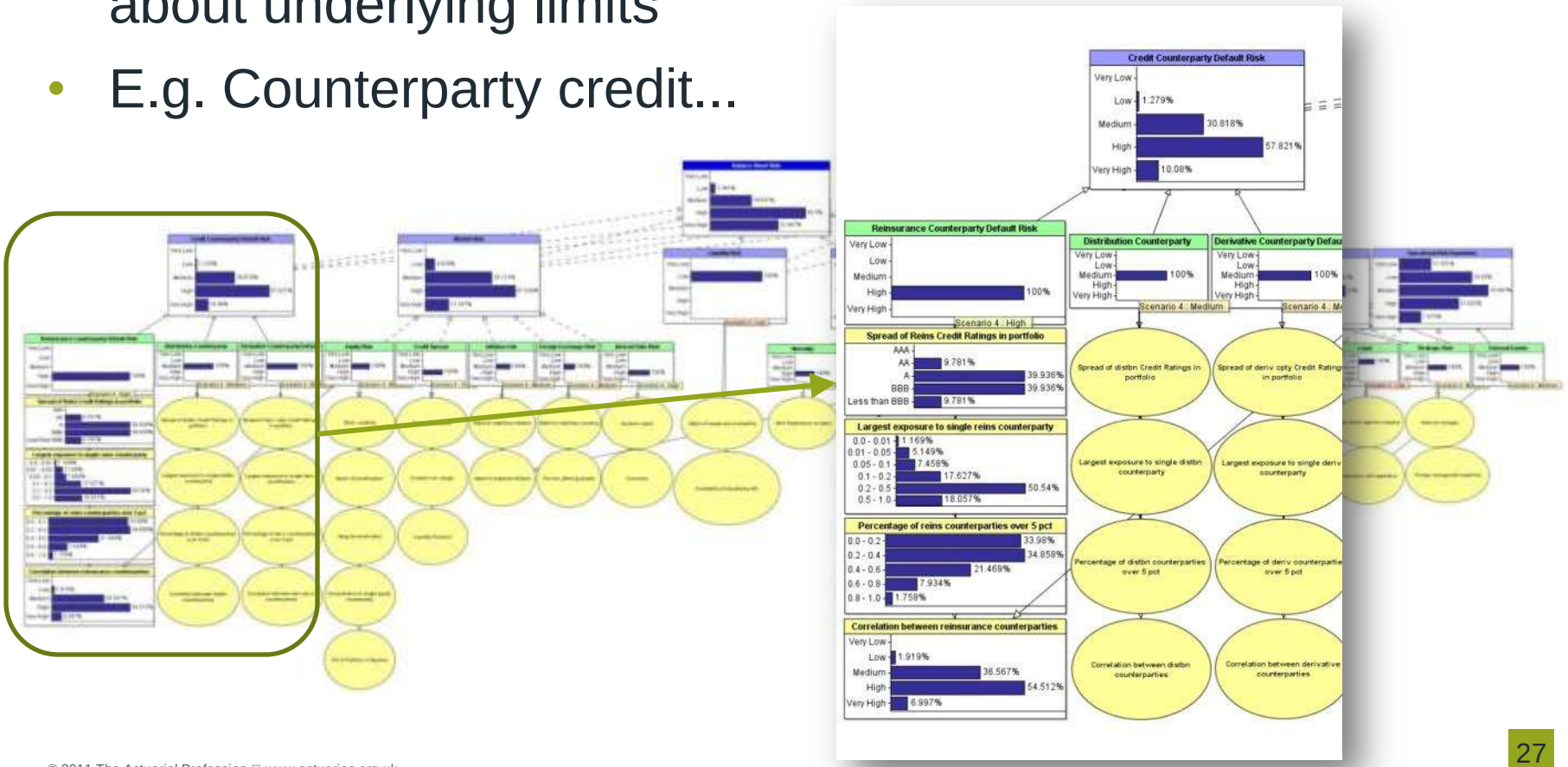
Setting an outcome here...



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

Propagating evidence

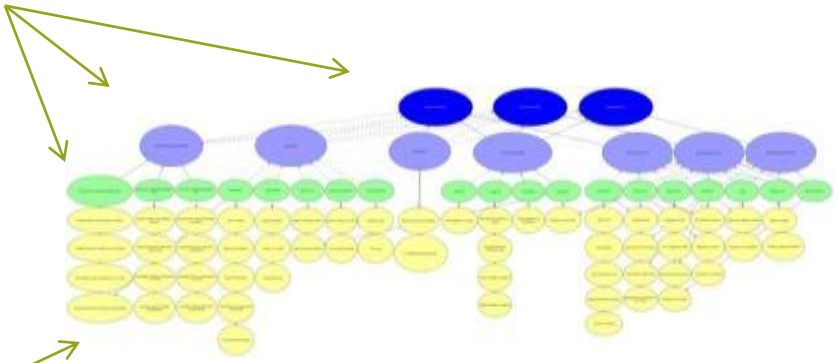
- Setting desired appetite level translates into information about underlying limits
- E.g. Counterparty credit...



Monitoring

- Use propagation properties of Bayesian Networks

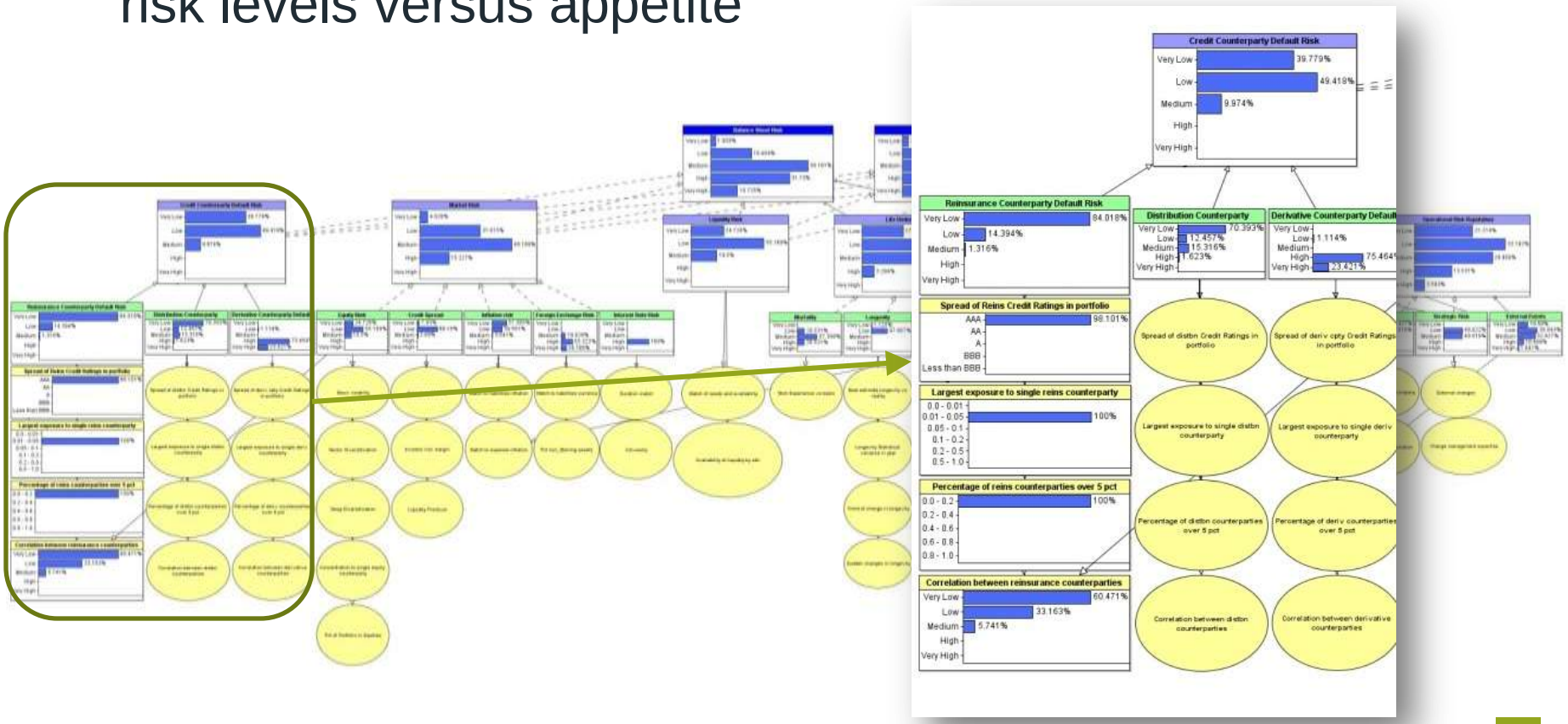
...gives us an estimate of risk level here



Entering observed values here...

Monitoring risk levels

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



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

The Actuarial Profession
making financial sense of the future

Applications of complexity science

Emerging Risk

From risk appetite to evolution and adaption

From risk appetite to evolution and adaption

From risk appetite to evolution and adaption

From risk appetite to evolution and adaption

Problem statement

- How can firms identify “hard to define or emerging risks”, and assess those risks in such a way that the underlying drivers and dynamics can be made transparent and hence included in building quantitative models.

An overview of Evolutionary Risk Approach

- Enterprise risk as an evolutionary process
- How can we model the risk evolution process
- What insight can evolution of risks provide
  - A rigorous classification system with relationships
  - A guide to emerging, dynamic and systemic risks
  - A unique organizational risk lineage
  - Powerful connectivity measure
- A case study

Does risk fit evolutionary criteria?

Biological Evolution	Linguistic Evolution	Enterprise Risk Evolution
Discrete characters	Vocabulary, combined sounds	Descriptions, causes, loses, Solvency II categories
Common ancestors	Words with common origin	Risks from common origin e.g. Fraud, pricing
Mutation	Innovation	Innovation, regulation
Natural selection	Social selection	Regulatory/Management selection
Horizontal gene transfer	Borrowing from other languages	Transfer of info between businesses and industries
Fossils	Ancient texts	Historic case studies, losses
Species splitting into others	Language Lineage Splits	Risk categories (strategic, operational, financial etc)
Extinction	Language death	Risk eradication

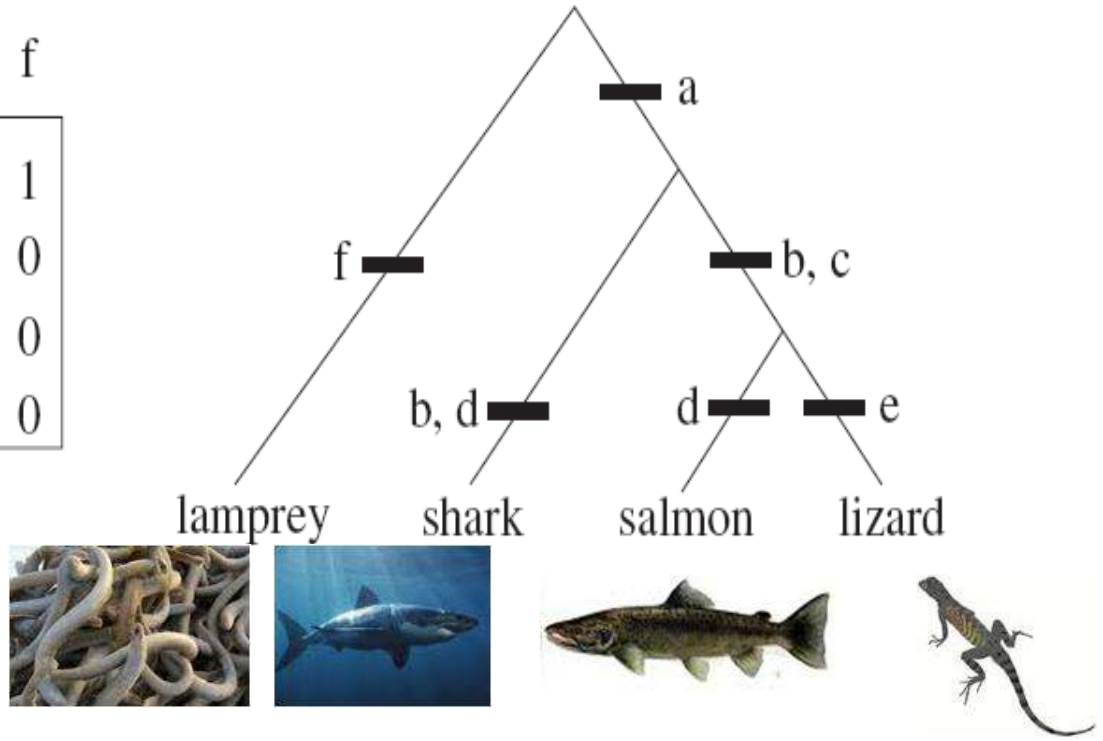
After Pagel (2009) Nature, see also McCarthy

Overview of Cladistics and Phylogeny

- This methodology identifies small groups of highly related risks which share a common ancestor
- The evolutionary history of each of these groups can then be accurately traced
- Then their relation to other groups investigated
- By understanding the phylogeny of the risks we can:
  - Determine where evolution is most prolific
  - Detail path dependency and co-evolution of risk
  - Identify the most active characteristics to manage
  - Create focused scenarios for emerging risks modelling

Cladistics technique - a simple example

	a	b	c	d	e	f
lamprey	0	0	0	0	0	1
shark	1	1	0	1	0	0
salmon	1	1	1	1	0	0
lizard	1	1	1	0	1	0



(a) paired fins, (b) jaws, (c) large dermal bones, (d) fin rays, (e) lungs, and (f) rasping tongue

The Actuarial Profession
making financial sense of the future

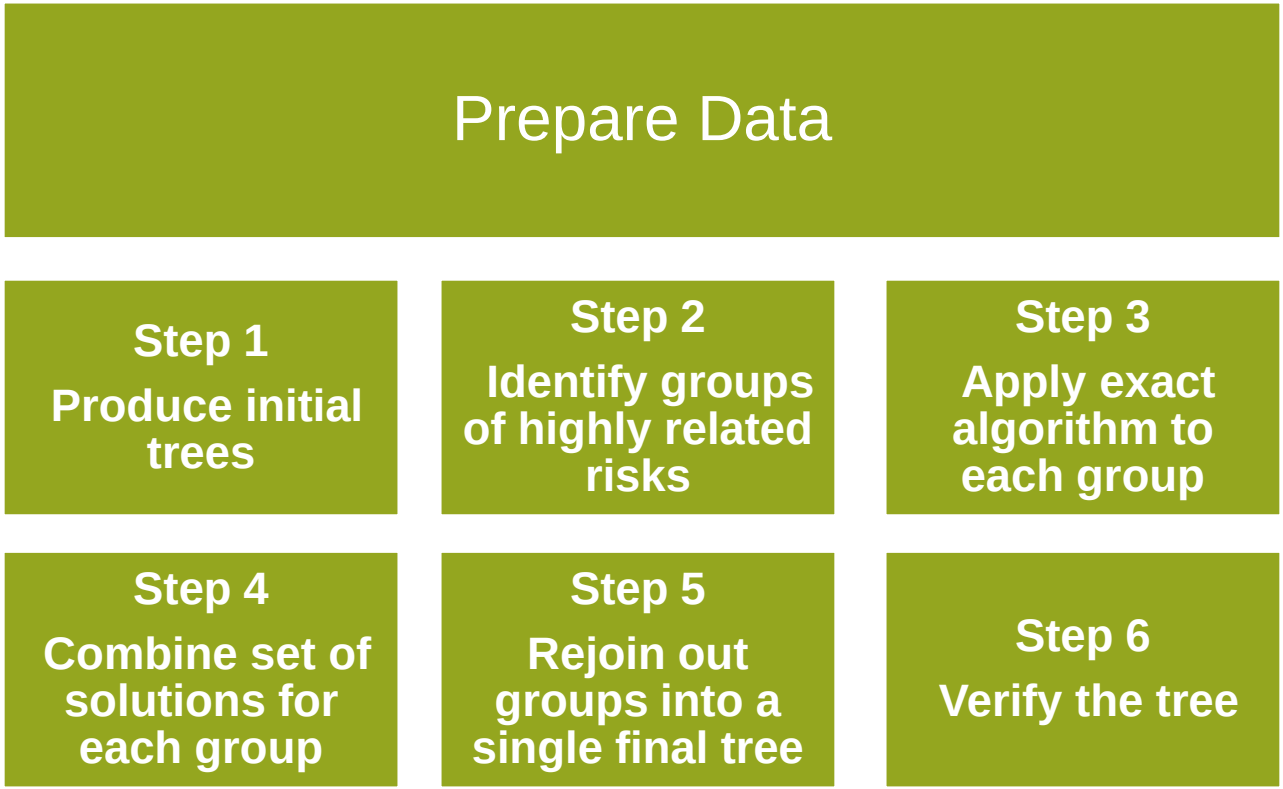
Construction and Verification of a Tree of Risk Evolution

Case study

Construction process

- No single software program exists for this new technique so there are some steps to integrate the process, which are:
  - Identifying the highly related groups (Mega)
  - Choosing the most parsimonious solution (Ctree & Mega)
  - Representing the output and evolutionary characteristics (Mesquite)

Constructing a tree of risk evolution



Data preparation

- 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 Ireland S&P downgrade.					
14	Outcome of test Achats by ECJ – EU gender directive decision.					

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

- 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.

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

- 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.

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

- 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?

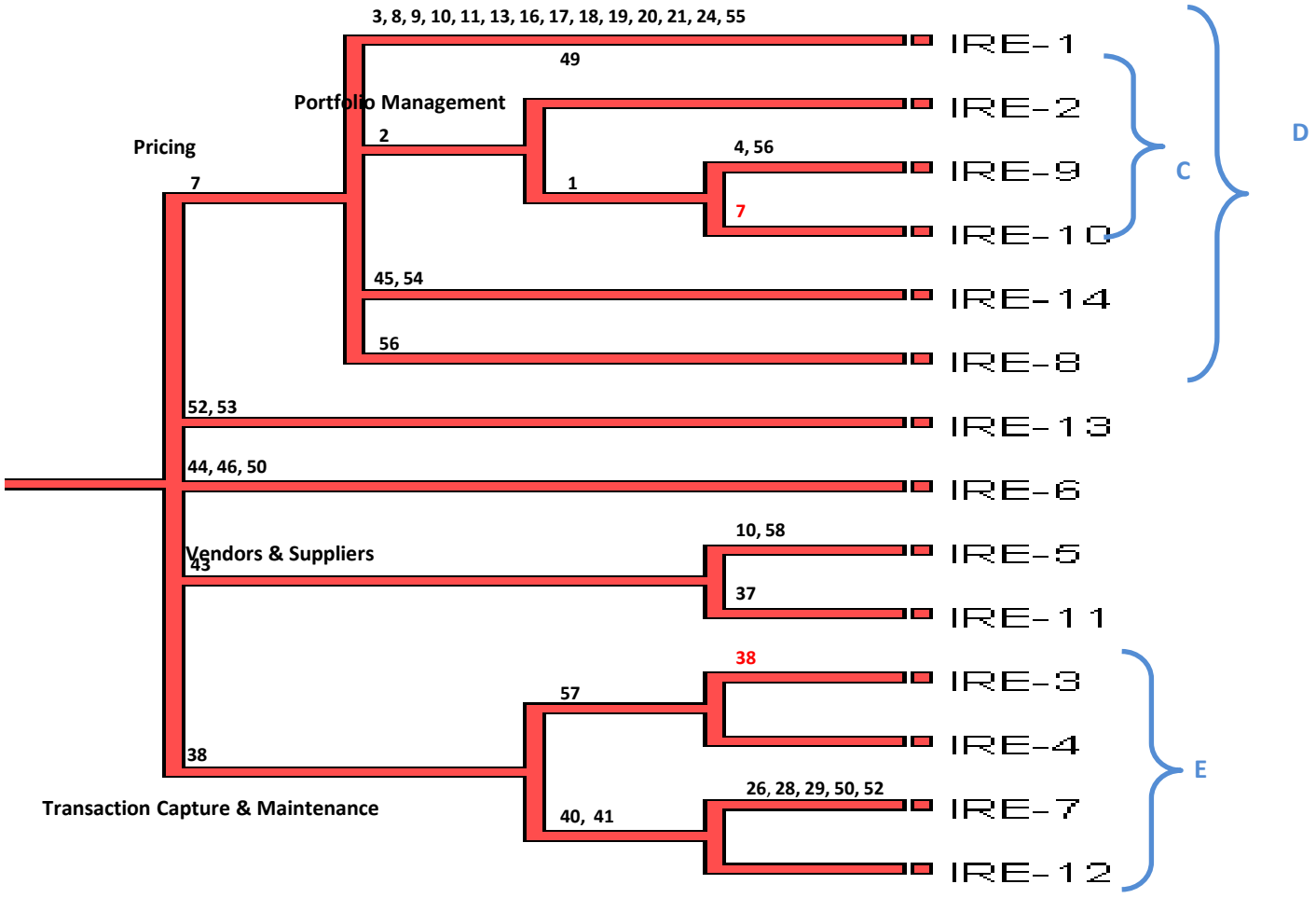
Risk Characteristics for this example

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

Interpreting Evolutionary Properties

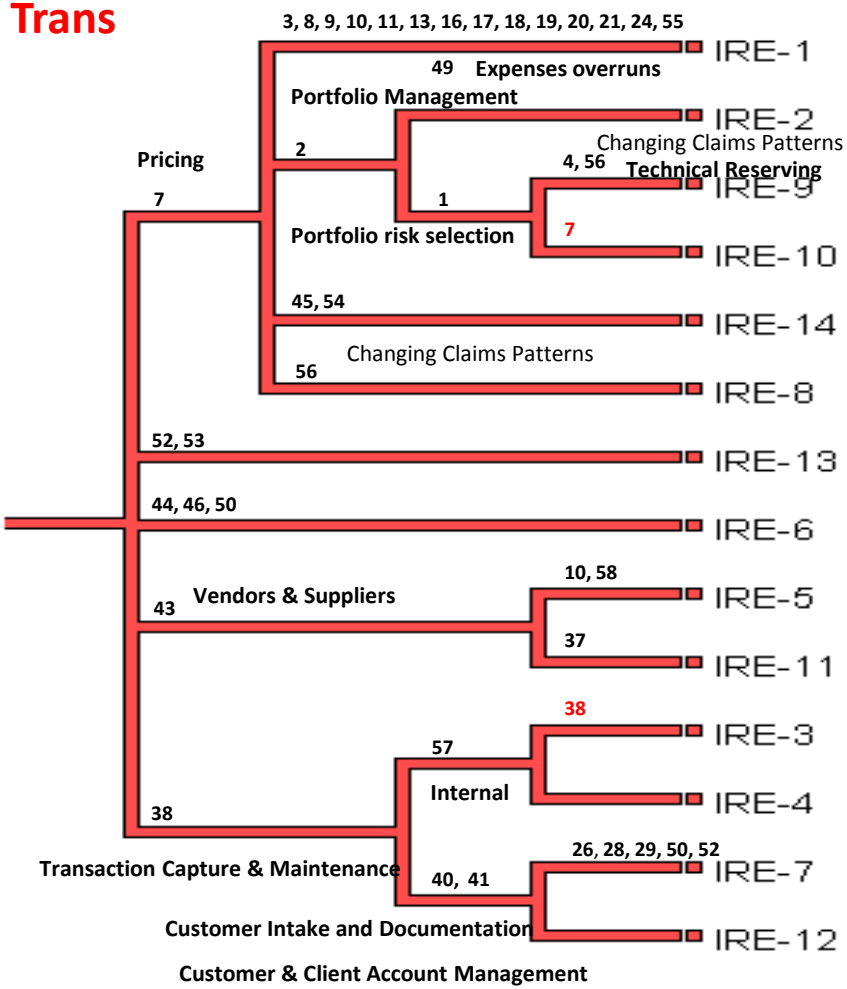
- Look at tree shape
  - areas of cascading bifurcation are likely areas for more evolution and therefore emerging risks
- Identify branches that have the most characters/adaptation
  - They are more likely to adapt again
- Find characters that evolve most frequently
  - Is there a character or pattern 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 Ireland Constructed tree – with Clades shown



Ireland

7 = Pricing
38 = Trans



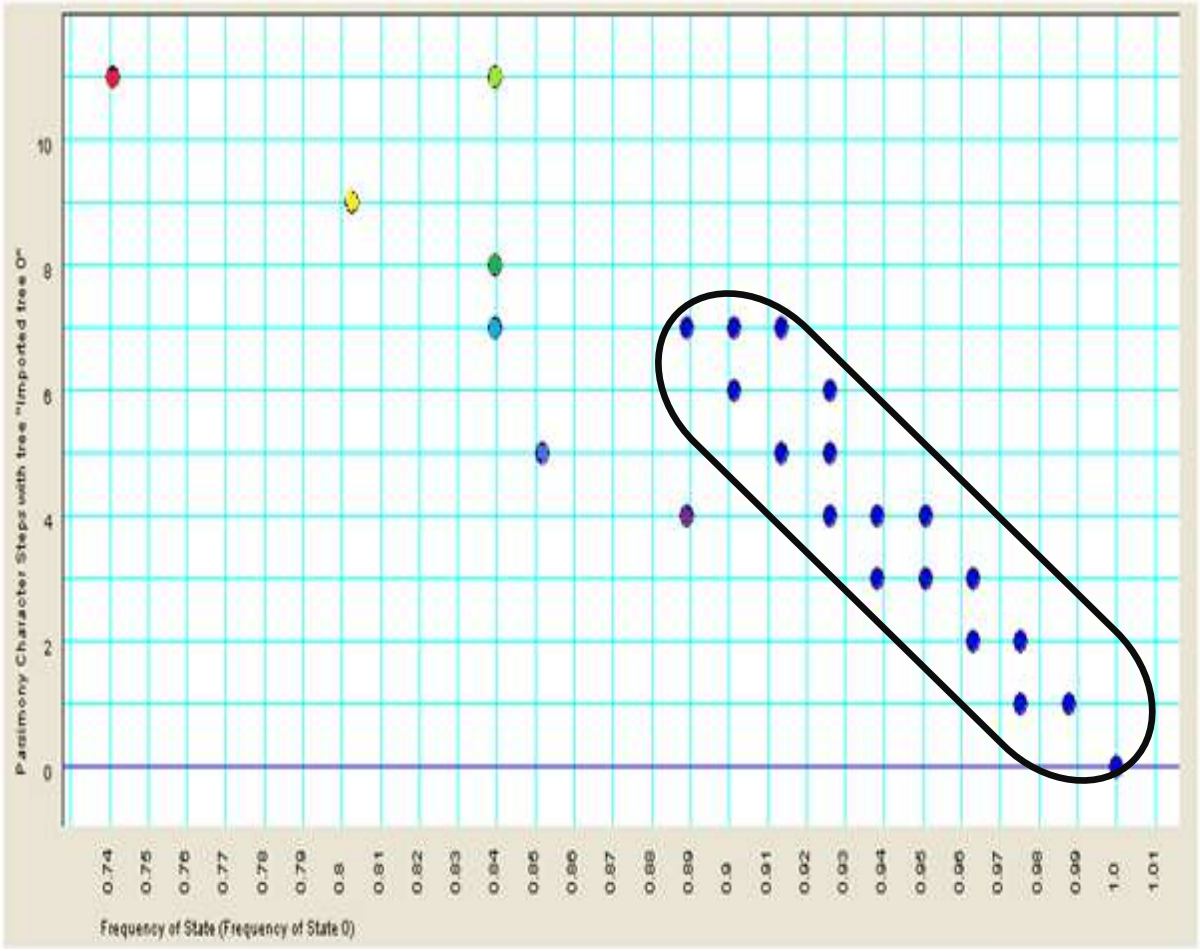
Economic Downturn
Under delivery of projected UW result
Repeat of catastrophic weather events
Implementation Periodic Payments
Outcome - EU gender directive
Prior Year claims on X Book

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

Questions for Ireland example

- ‘Economic downturn’, indeed is complex and could easily have another character attach and also could split into something else eg Euro crises, Housing crises, Japanese Earthquake
- Risk Ire 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 in Ire – one for management.

Characters frequency v parsimony steps



- **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**

UK

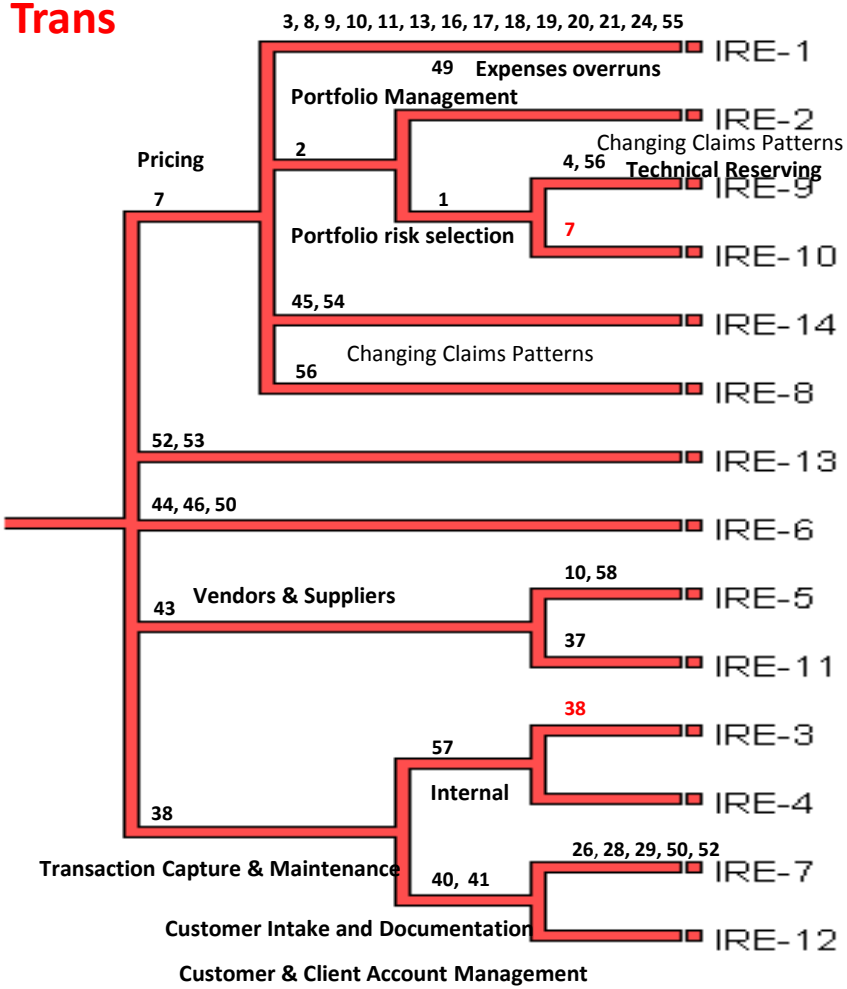
		1 Underwriting Risk						
Risk ID	Risk	1.1 Portfolio risk selection	1.2 Portfolio Management	1.3 Claims management	1.4 Technical Reserving	1.5 Reinsurance arrangements	1.6 Longevity risk (Pension)	1.7 Pricing
1	Fail to recognise and protect portfolios against the effects of larges losses and abnormal weather	1	1			1		1
2	Current review by Lord Chancellor requires reserve strengthening for Ogden lump sum awards							1
3	Adverse Bodily Injury trends continue to rise	1		1				1
4	Insufficient rate within Commercial Property portfolios to achieve required risk adjusted return							1
5	Fraud trends continue to rise			1				
6	Focus on top line leads to a failure to maintain underwriting, pricing and controls discipline resulting in negative bottom line impact	1	1	1				1
7	Inadequate reserves to cover Disease (asbestos, deafness, vibration white finger) and Abuse claims			1	1	1		
8	The European Court of Justice rules against gender based risk pricing in insurance contracts (Achats)							1
9	Periodic Payment Orders (PPOs) adversely impact current reserve levels			1	1			
10	Lack of capacity for key initiatives, deals and change programmes resulting in poor execution and / or poor integration							
11	Systemic Credit risk event such that default levels on unsecured credit reach 1991 levels or default of a major counterparty							
12	Poor control of Delegated Authority Schemes business results in a loss							
13	Fail to achieve business case for key initiatives, deals, change programmes							
14	Inflation drives adverse impact on expense base and claims cost							
15	Fail to adapt and implement changes to the regulatory architecture, including Solvency II							

Comparing trees

- Both have pricing Clades, both prominant
- Look at structure of the Clades
  - Is one more logical than another?
  - Why might that be is there a reason?
  - Why is character 5 missing (reinsurance provision from Ire)
- Character 54 is in both clades but why not 45 ‘Increase in regulatory costs’ in the UK

Ireland

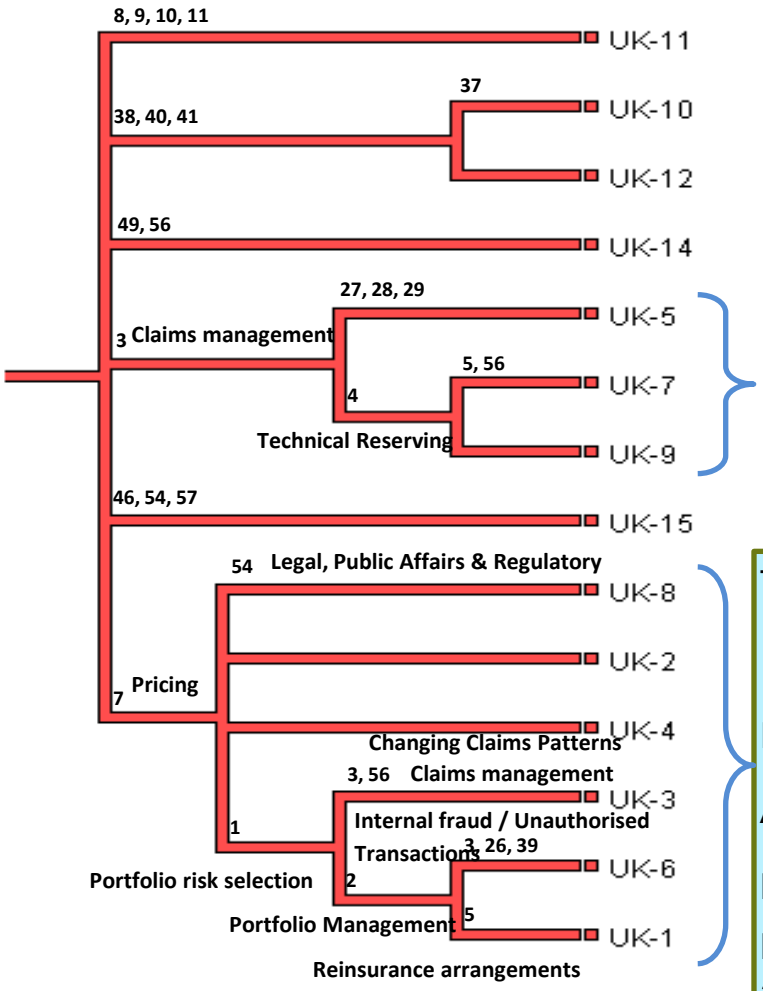
7 = Pricing
38 = Trans



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

UK Tree



Fraud trends continue to rise

Inadequate reserves to cover Disease and Abuse claims

(PPOs) adversely impact current reserve levels

The European Court of Justice rules against (Achats)

Review by Lord Chancellor requires reserves rise

Insufficient rate within Commercial Property portfolios

Adverse Bodily Injury trends continue to rise

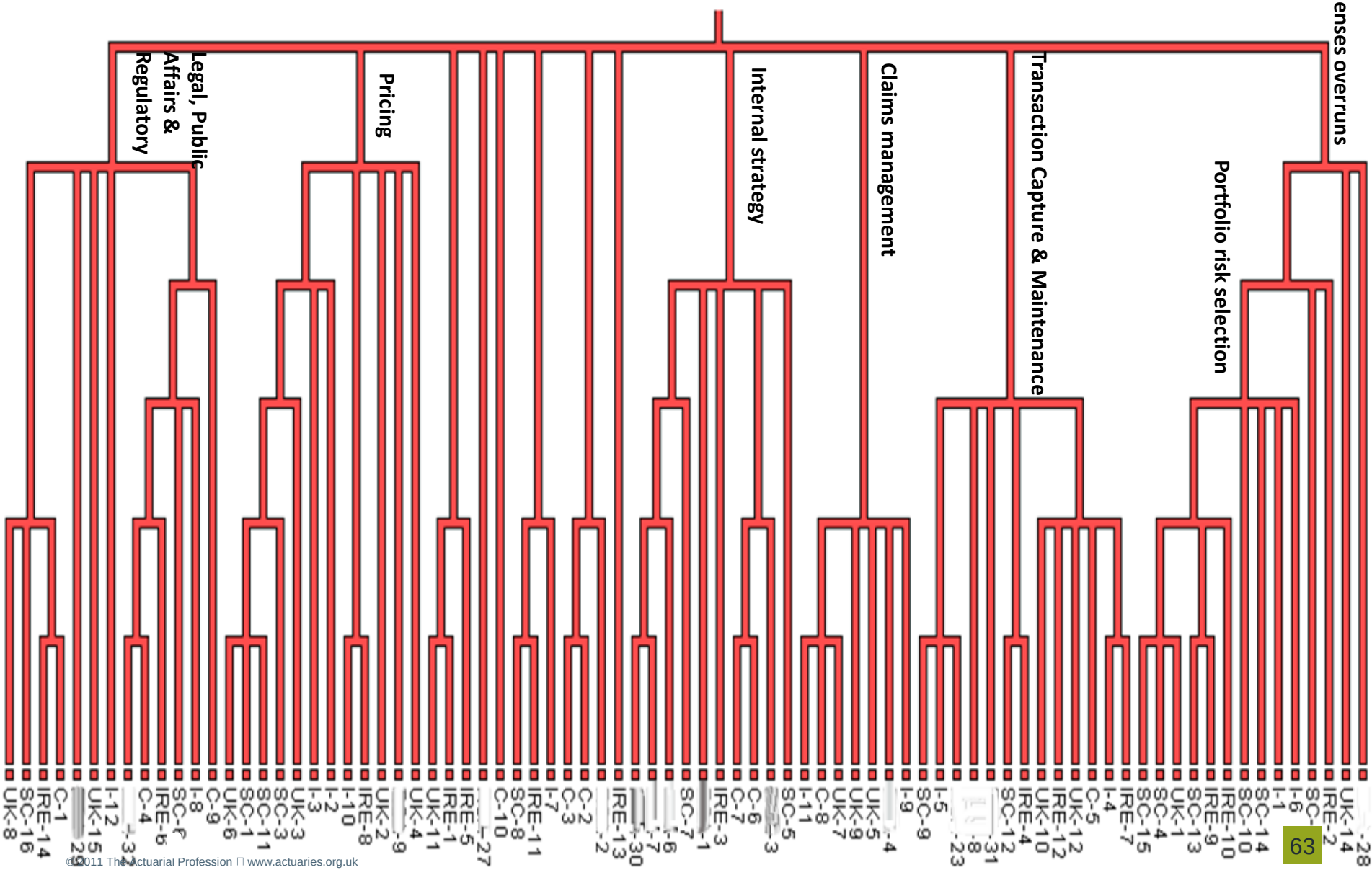
Failure to maintain underwriting, pricing and controls

Fail to protect portfolios against larges losses and abnormal weather

Co-evolution? For instance:

- E.g. Risk IRE (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). IRE (7) has (52) but not (53)
- Risk ‘IRE-5’ ‘Business does not achieve planned growth’ has ‘Insurance operations credit risk’ (10) and may gain Reinsurance Credit Risk (8), Insurance Products Credit Risk+A23 (9) and Invested Assets Credit Risk (11). Why?
  - Reinsurance Credit Risk (8), Insurance Products Credit Risk+A23 (9), Insurance operations credit risk (10) and Invested Assets Credit Risk (11) All evolve simultaneously in ‘IRE-1’ and ‘UK-11’.

All countries added to one tree – same principles



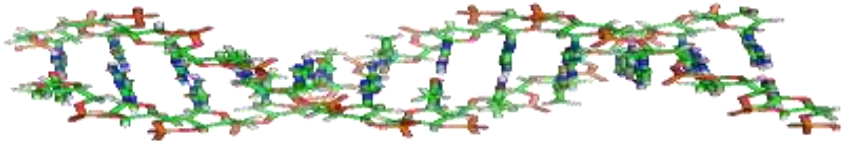
General overview

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

Evolutionary connectivity of risks by country

Risk	Score	Risk	Score	Risk	Score	Risk	Score	Risk	Score	Risk	Score
UK-3	13	SC-4	19	XX-30	7	IRE-9	8	I-3	8	C-2	12
UK-6	12	SC-1	18	XX-7	6	IRE-2	6	I-2	6	C-1	11
UK-1	9	SC-11	17	XX-23	5	IRE-7	6	I-10	6	C-3	10
UK-7	8	SC-3	14	XX-32	4	IRE-1	5	I-11	6	C-8	6
UK-8	6	SC-15	13	XX-6	3	IRE-8	5	I-1	5	C-9	6
UK-2	5	SC-13	12	XX-1	2	IRE-12	4	I-9	4	C-6	5
UK-4	5	SC-14	12	XX-4	2	IRE-14	4	I-8	2	C-7	5
UK-9	5	SC-2	11	XX-31	2	IRE-4	3	I-12	2	C-5	4
UK-5	4	SC-10	9	XX-3	2	IRE-10	3	I-4	1	C-4	3
UK-10	3	SC-7	5	XX-8	2	IRE-5	2	I-5	1	C-10	0
UK-12	3	SC-5	4	XX-2	1	IRE-3	1	I-6	1		
UK-14	2	SC-6	4	XX-28	1	IRE-6	1	I-7	0		
UK-15	1	SC-12	4	XX-29	1	IRE-11	1				
UK-11	0	SC-16	4	XX-9	0	IRE-13	1				
		SC-9	3	XX-27	0						
		SC-8	1								

Risk evolution – Summary

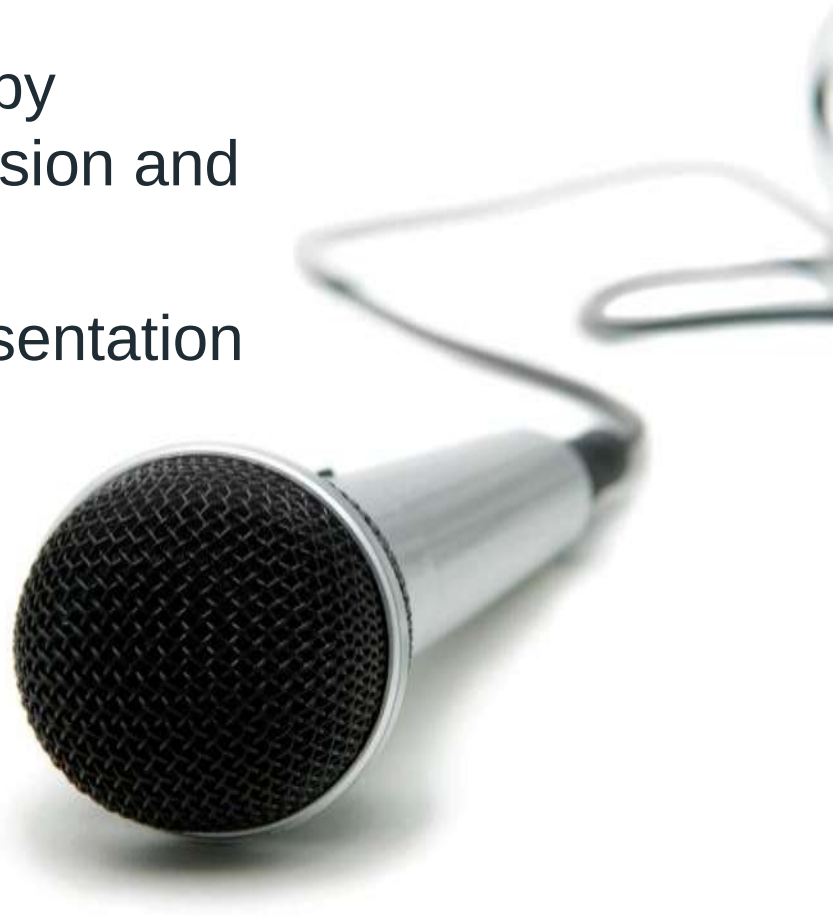


- Risks have a unique DNA which can be mapped
- With good data phylogenetic techniques can produce reliable evolutionary information about:
  - classification, dynamics, direction, connections, interdependence, highly influential characters
  - how a risk reached a certain state and how it might evolve
  - how controls and environment affect the risk system

Questions or comments?

Expressions of individual views by members of the Actuarial Profession and its staff are encouraged.

The views expressed in this presentation are those of the presenter.



© 2011 The Actuarial Profession • www.actuaries.org.uk