The Actuarial Profession
making financial sense of the future

Open Forum – 21st January 2011
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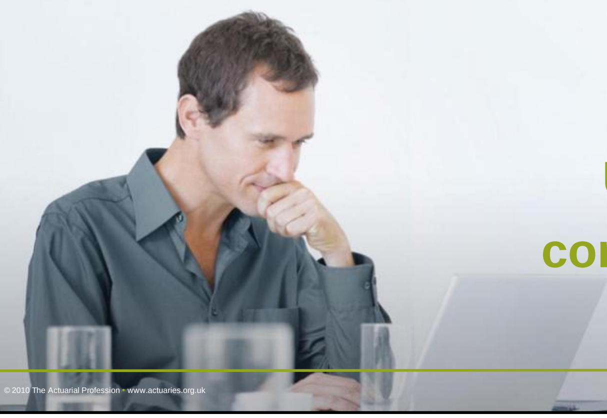

Unravelling the complexity of risk

Plan for this session

- Why is a new approach needed and why now?
- Overview of complex adaptive systems (CAS)
  - What are they?
  - Why should you be interested?
  - Basis of the science behind CAS
- Are companies and organisations CAS?
- Can risks be modelled as a CAS?
- Examples of applications for the profession
- Open discussion and questions

1

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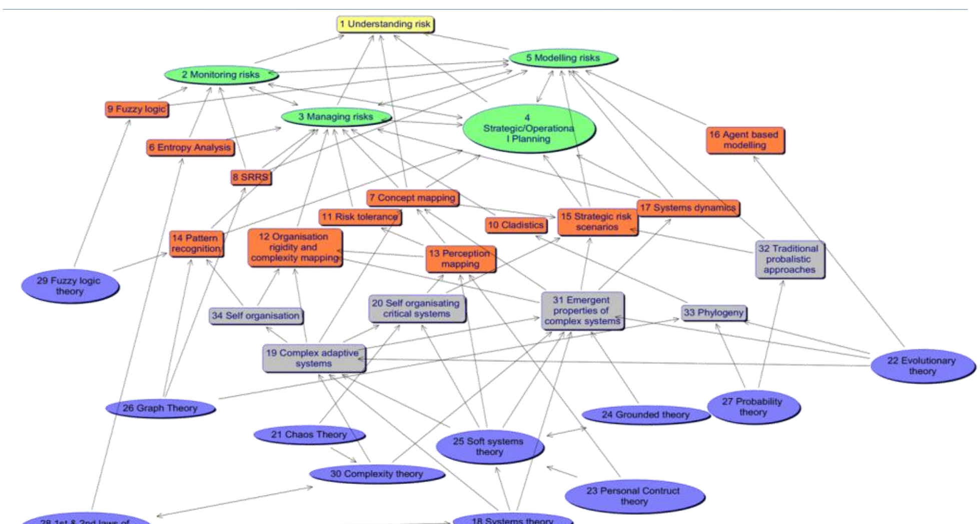
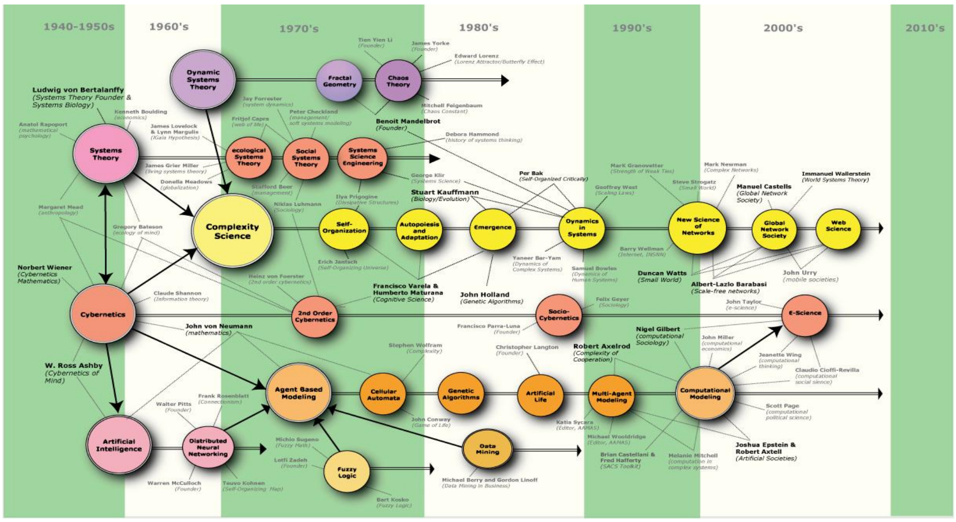
Unravelling the complexity of risk

Overview of complex adaptive systems

Path to our understanding



Roadmap of the development of complexity science



Systems Thinking

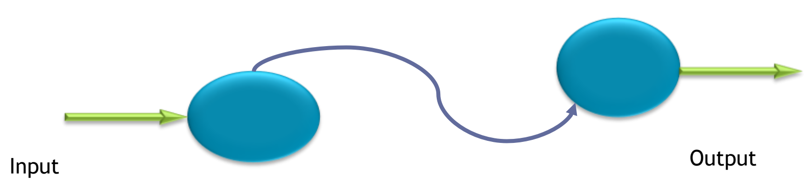
- Systems thinking is both a worldview that:
  - Problems cannot be addressed by reduction of the system
  - System behaviour is about interactions and relationships and
  - Emergent behaviour is a result of those interactions
- And a process or methodology
  - To understanding complex system behaviour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

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.

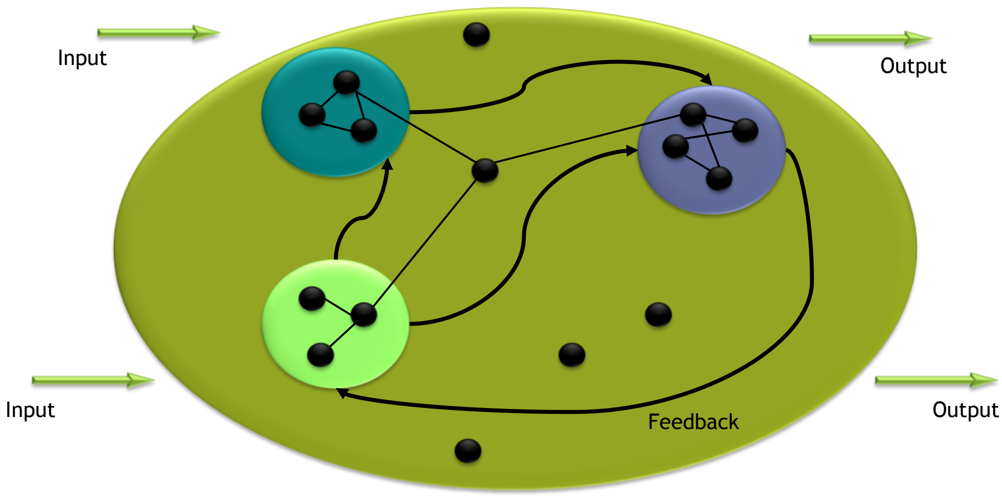
The goal of complexity science is to understand complex systems: what ”rules” govern their behaviour, how they manage change, learn efficiently and optimise their own behaviour.

What is a system ?



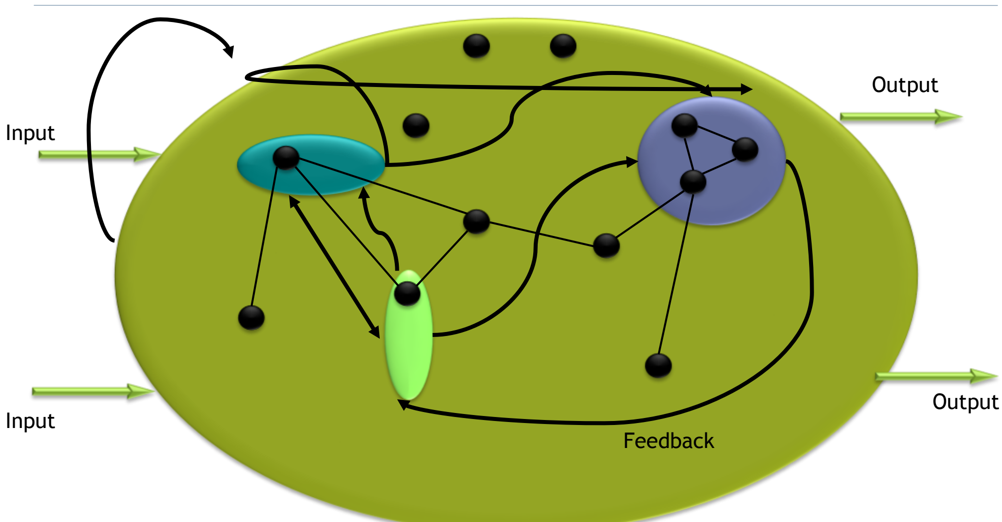
“a set of components interconnected for a purpose.”

What is a *complex* system ?



8

What is a complex *adaptive* system ?



Elements can change

9

Complex Adaptive Systems

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

A System and a Heap

A system	A heap
Interconnecting parts functioning as a whole	A collection of parts
Changed if you take away pieces or add more pieces.	Essential properties are unchanged whether you add or take away pieces.
The arrangement of the pieces is crucial	The arrangement of the pieces is irrelevant
The parts are connected and work together	The parts are not connected and can function separately
Its behaviour depends on the total structure.	Its behaviour (if any) depends on its size or on the number of pieces in the heap.

(O'Connor and McDermott, 1997)

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

12

Emergence – E.g. Music

You can explore the characteristics of individual notes

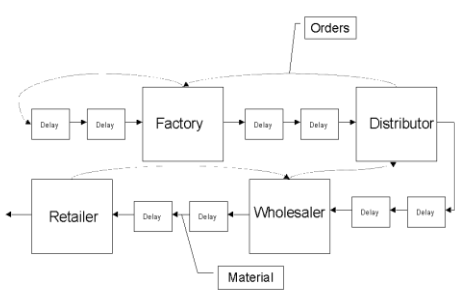
...but you cannot know the tune without knowing the interactions (score)

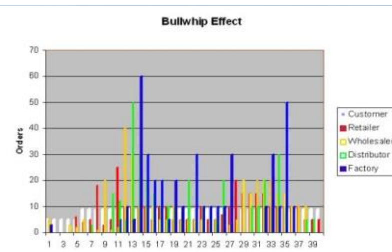
13

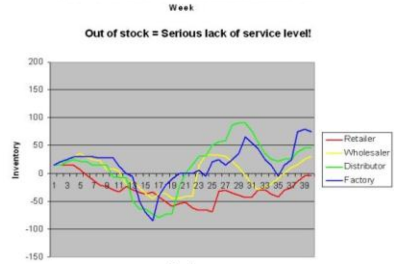
Self-Organisation and emergence

Non-linearity

- The Beer Game (MIT, 1960's)







Source: www.beergame.org

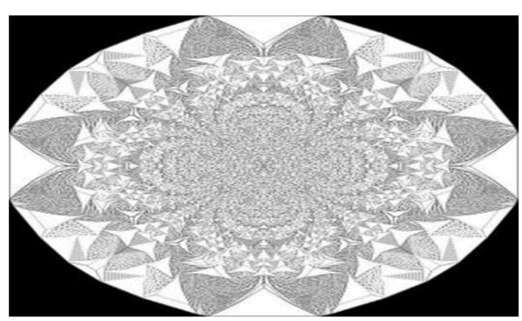
Unintended consequences

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

16

Examples of tipping point collapse

- Liquidity crunch
- Cutting down too many trees
- Relying on debt
- Building too many offices or residences
- Ozone layer, ground water, agricultural soils etc
- Sand pile

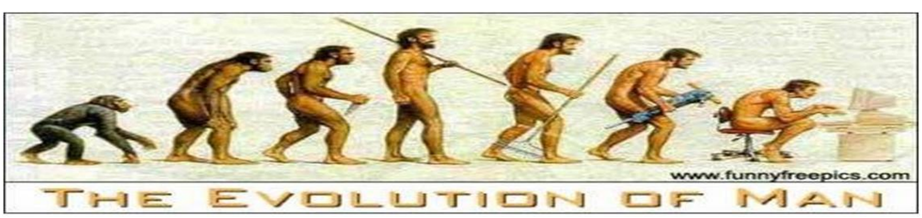


17

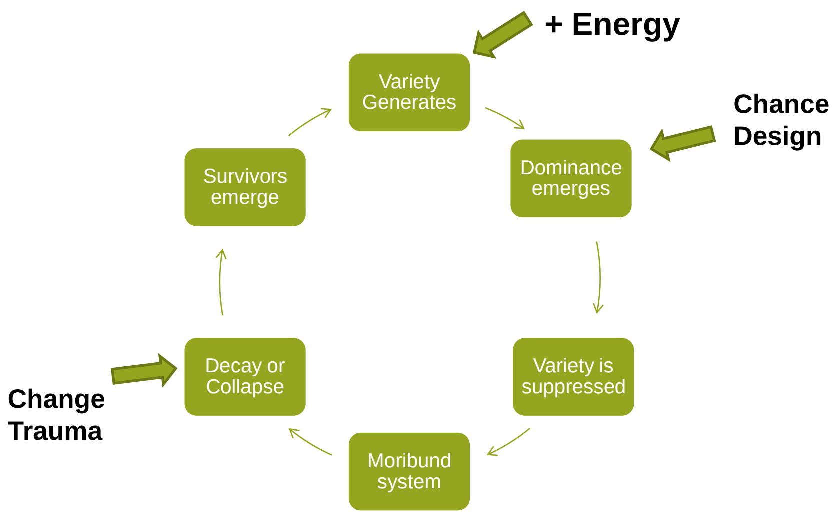
Causes of tipping point & overshoot

- Poor understanding of the level and the causes of the limit
  - Humans are not perfectly rational
  - They suffer bounded rationality
  - Mental models incomplete / insufficient time to consider them
  - Can't even mentally simulate a first order linear feedback loop
- Tendency to be focused on indirect, delayed indicator for health of system
- Momentum in the system and positive reinforcing loops
- Long delays in deciding, responding & affecting change
- Competition and focus on short term measures (long-term response may be different to short-term one)

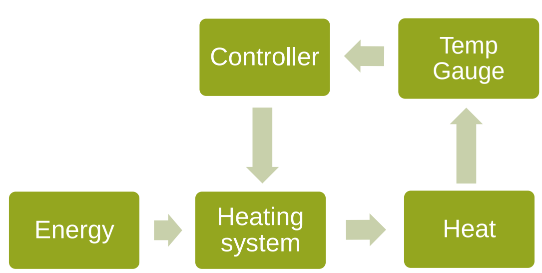
Evolution – path dependency and history



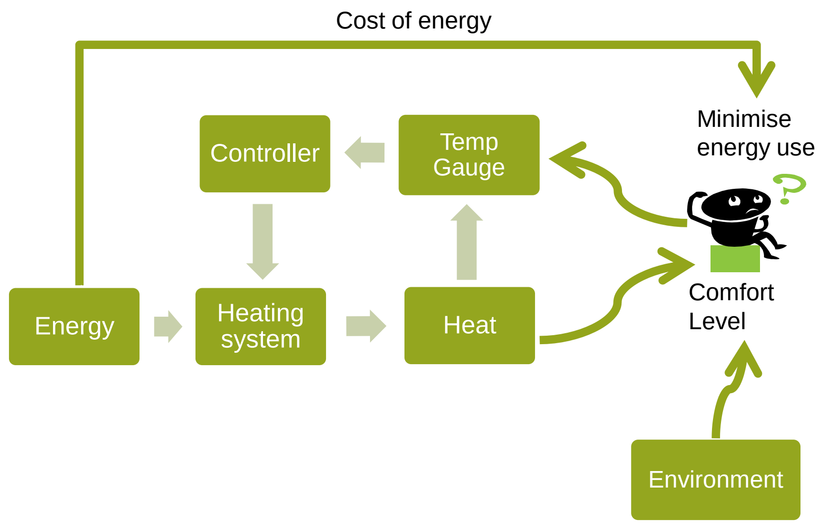
Entropic cycling (after Hitchens)



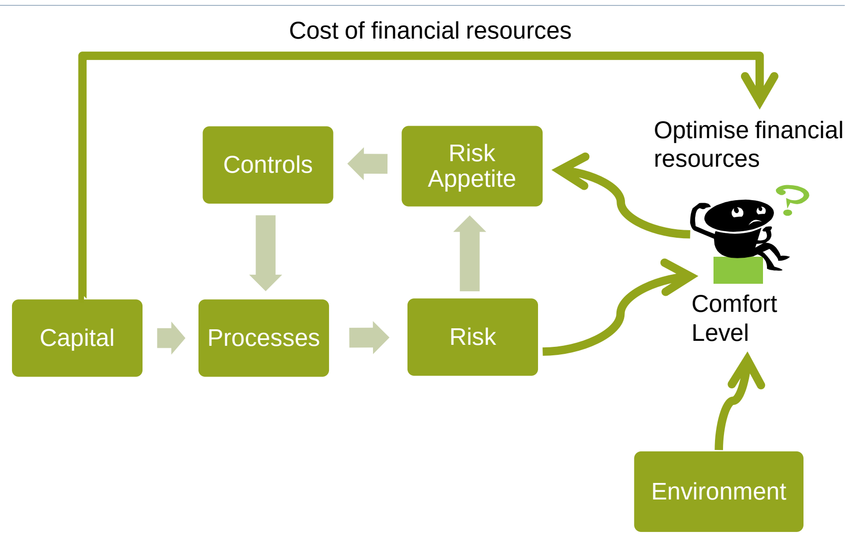
Idealised heating system



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 systems critical complexity trajectory

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Unravelling the complexity of risk

Are companies complex adaptive systems?

Relevance to Companies

- Companies are CAS because they consist of people who are:
  - Adhering to cultural norms, beliefs, principals
  - Following processes, learning, adapting, interdependent
  - Communicate, use initiative, often irrational, interact
- The industry and related companies are self-organising
- External environment is changing and impacts companies
- Emergent behaviour brings significant new systemic risks
- Evolution and history is important

The human factor

"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)

Organisations as complex systems

- Organisations are segmented rather than monolithic
- Stable segments within organisations are quite small
- Connections between segments are of varying strength, and they produce ambiguity
- The way information flows and interactions occur matters because:
  - Influences culture, hierarchy and structure
  - Impacts on speed of communication

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Unravelling the complexity of risk

Can risks be modelled as a complex adaptive system?

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

Motivation For New Approach

- Conceptual framework typically used for risk is flawed
  - Risk is an emergent property so aggregating the behaviour of components cannot tell you about the whole
- Risk assessment nearly always relies upon human judgement
  - Humans are not good at assessing risk
- Frameworks provide limited predictive capability
  - Models focus on outcomes not real drivers
- Business has become increasingly complex and techniques are still about linear behaviours and “normal” distributions

- Time to evolve

Mis-Framing Risk

- Traditional risk management approaches oversimplify
  - Makes modelling more tractable
  - Makes data easier to organise
  - But does not describe how risks really behave
- Risks are
  - Treated as events which happen at a point in time
  - Characterised by a single “dominant” feature
  - Considered as being homogeneous according to that label
- In slow-moving benign conditions these assumptions work OK
- In a complex environment they really don’t

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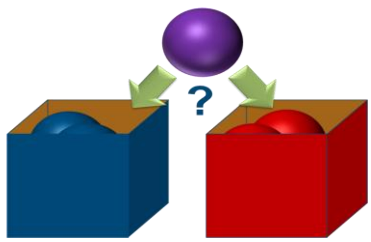
Unravelling the complexity of risk

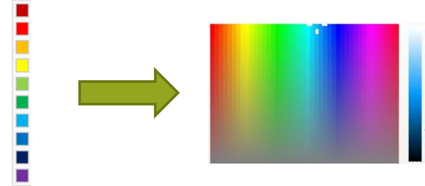
Examples of applications for the Profession

But first...don't oversimplify

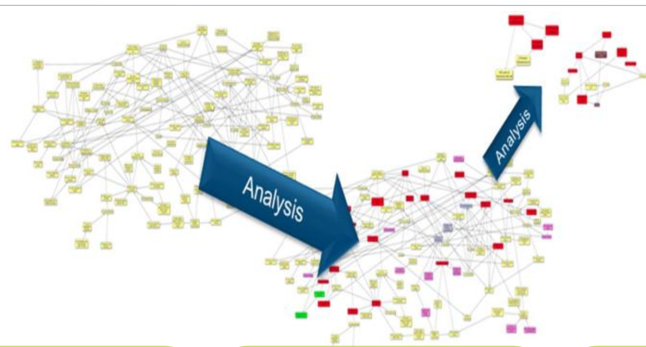
- Looking for patterns needs information
- Many attempts to monitor risk throw that away at outset
- Don't guess in advance what you expect to see
- Need a "model-free" approach to see emergence

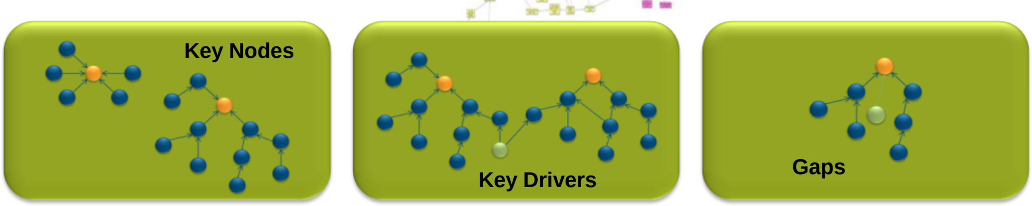


Allow people to "mix" colours



Understanding The System

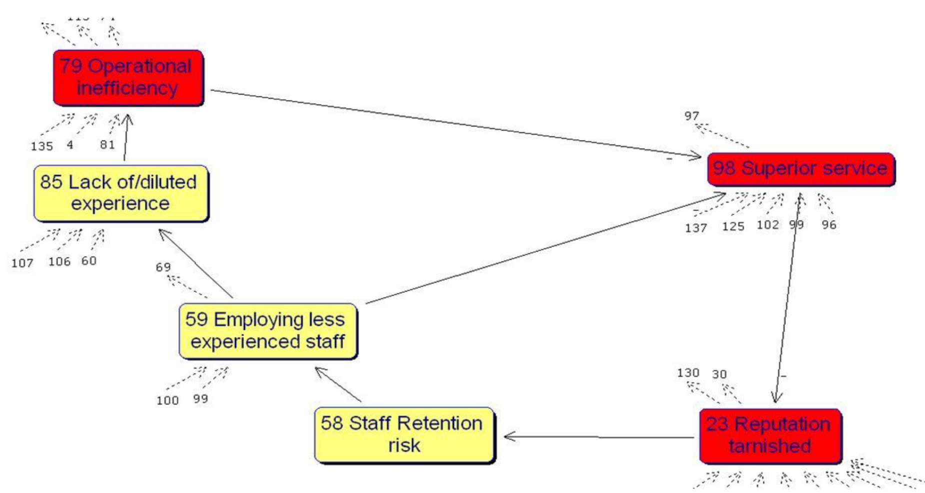




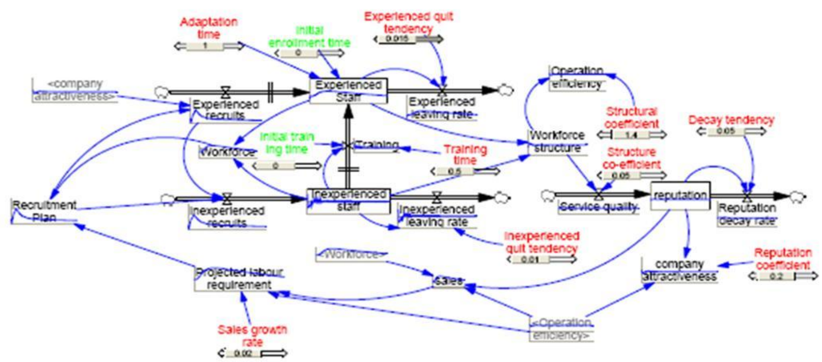
Cognitive Mapping

- The theories we use here are based around:
  - Personal Construct Theory (*George Kelly 1955*) – you know your environment
  - Grounded Theory (*Glaser and Strauss 1967*) – generate a theory from the research
  - Cognitive mapping (*Colin Eden, Fran Akermann and Steve Cropper 1990*) – combine multiple "theories" to form single perspective of a problem

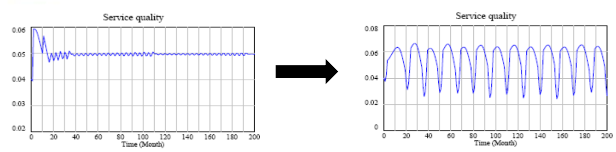
A Dynamic Loop From Cognitive Map



Can Be Modelled With Systems Dynamics



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



Applications

- Rapidly elicit highly detailed description of risk profile and implicit dynamics
- Feeds into:
  - Business planning
  - ORSA
  - Scenario development (and hence modelling)
  - Risk appetite framework
  - Emerging risk identification

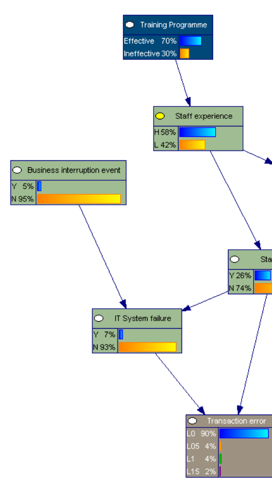
Influence Modelling

- 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

Bayesian Networks

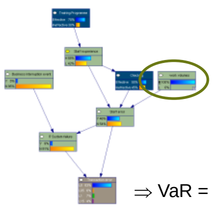
- Permits more transparency and better engagement from business
- Combinations of earlier tools can help to determine relevant key drivers of risk outcome

SIMPLE EXAMPLE



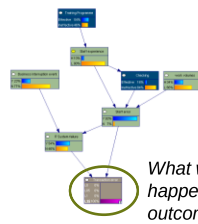
⇒ VaR = £1.40m (99.5%)

Bayesian Networks (2)



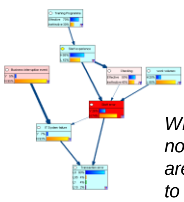
What if work volumes are high?

⇒ VaR = £1.44m (99.5%)

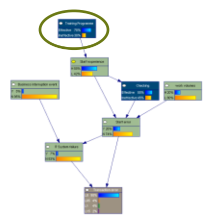


"Evidence" of outcome propagates back up the model

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)

Bayesian Networks (3)

- Advantages:
  - Easier to test sensitivities/what-if analysis
  - Combines hard and soft data
  - Incorporate hard and soft evidence
  - Fast – no simulation
  - Can be projected sensibly through trends in drivers
  - Easy to communicate
  - Can combine with statistical models
  - Easy to establish risk monitoring linked to model components

Applications

- Operational risk modelling
- Scenario modelling for extreme risks
- Risk appetite and limit setting

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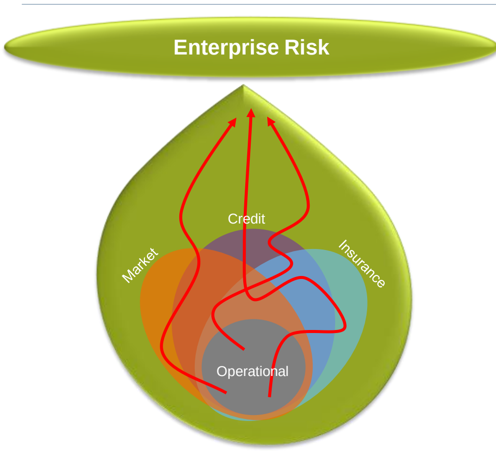
Evolution is a signature of complex systems

Typical Approach To Risk Identification

- 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

What Risk Really Looks Like



- Looking at real risks we see they have multiple characteristics
- They combine to produce “new” outcomes
- By seeking to understand the forces driving these dynamics
- ...we can spot risks early
- ...and make better judgement about what matters

Risk evolution

- Produces reliable evolutionary information such as classification, direction, connection
- It demonstrates how a risk reached a certain state and how it might evolve
- Understanding the risk "DNA" enables modelling to show which risk areas are currently most prone to emerge as the new strain or breed of risks

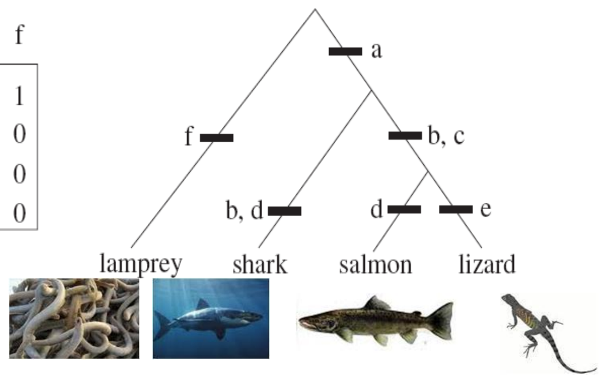
Comparison of Biological, Linguistic, Enterprise Risk

Biological Evolution	Linguistic Evolution	Enterprise Risk Evolution
Discrete characters	Vocabulary, syntax, sounds	Causes, loses, risk registers
Common ancestors	Words with common origin	Risks from common origin
Mutation	Innovation	Innovation, regulation
Natural selection	Social selection	Management selection
Horizontal gene transfer	Borrowing from other languages	Transfer of info between businesses and industries
Fossils	Ancient texts	Historic case studies
Species splitting into others	Language Lineage Splits	Risk categories (strategic, operational, financial etc)
Extinction	Language death	Risk eradication

After Pagel (2009) Nature

Cladistics 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

Analysing Risks Using Multiple Characteristics

- Determine risk characteristics (example)

Strategic	1	Strategy		
Market	2	Asset allocation	3	Concentration
	4	Other		
Credit	5	Investments	6	Reinsurance
	7	Other		
Insurance	8	Insurance		
Operational	9	Unacceptable business practices	24	Mishandling of investment transactions
	10	Internal control violations	25	Liquidity needs unmet
	11	Project failures	26	Mis-pricing/design of products
	12	Communication failure	27	Mishandling of underwriting
	13	Brand abuse	28	Inadequate reinsurance
	14	Violation of reporting regulations	29	Inadequate claim management
	15	Solvency	30	IT systems failure
	16	Violation of disclosure requirements	31	Unauthorized access to data
	17	Customer due diligence	32	Inadequate functionality
	18	Product compliance	33	Inappropriate skills
	19	Mis-selling	34	Staff act outside authority/competence
	20	Mishandling data	35	Business interruption
	21	Incomplete documentation	36	Adverse legal/regulatory change
	22	Systemic reporting error	37	Other
	23	Mishandling of complaints		

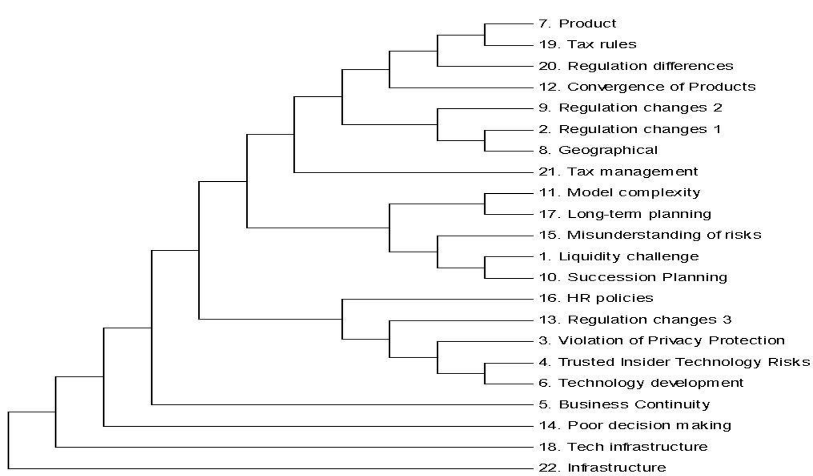
Analysing Risks Using Multiple Characteristics

Now categorise risks according to "all" the characteristics they have

Risk Scenario	Characteristic Number
1. Liquidity challenge	25
2. Regulation changes 1	1, 15, 16, 17, 18, 19, 26, 33, 36
3. Violation of Privacy Protection	9, 10, 12, 14, 17, 20, 21, 31, 34
4. Trusted Insider Technology Risks	10, 31, 34
5. Business Continuity	12, 30, 35
6. Technology development	10, 31, 34, 35
7. Product	26, 36
8. Geographical	1, 2, 8, 18, 19, 26, 36
9. Regulation changes 2	17, 19, 36
10. Succession Planning	33
11. Model complexity	21, 22, 32
12. Convergence of Products	1, 26, 36
13. Regulation changes 3	9, 10, 34, 36
14. Poor decision making	1, 35, 37
15. Misunderstanding of risks	2, 3, 12
16. HR policies	9, 10, 12, 37
17. Long-term planning	1, 32, 33, 36
18. Tech infrastructure	30, 35, 37
19. Tax rules	16, 26, 36
20. Regulation differences	18, 26, 36
21. Tax management	26
22. Infrastructure	30, 35, 37

52

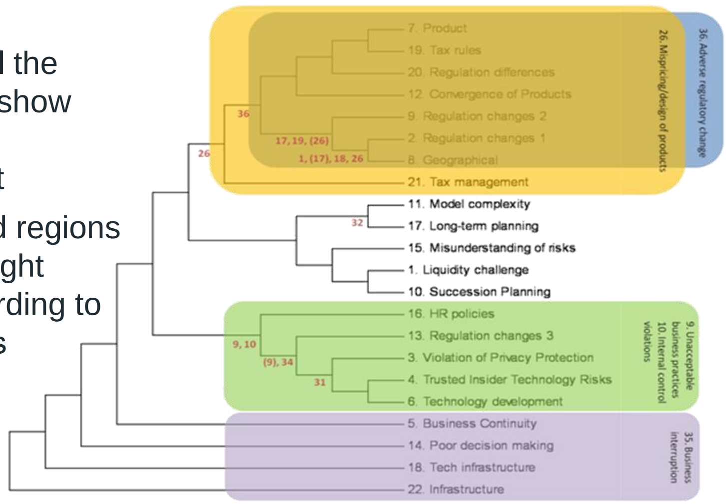
Compute cladistic tree



53

Interpretation knowing path dependancy

- We can label the branches to show “ancestor” development
- The coloured regions help to highlight groups according to “early” genes



Emerging issues

- Risk profile continues to evolve (lots of short branches), potentially indicating risks not being controlled
- We can see risk #13 is actually not much like the other regulatory risks and seems to be more like “control” failure risks
- Technology seems to be linked to control failure in this firm
- Much of the regulatory risk is to do with products

Evolutionary connectivity measure

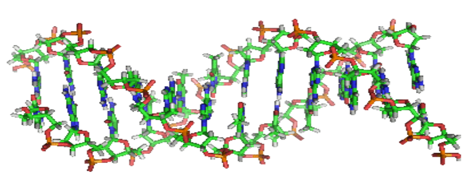
- Some risks are quite close to many others. Likely to find emerging risks including traits of these risks

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Liquidity challenge																					
2. Regulation changes 1	2.955																				
3. Violation of Privacy Protection	2.955	3.319																			
4. Trusted Insider Technology Risks	0.168	3.093	0.455																		
5. Business Continuity	0.168	3.093	2.955	0.455																	
6. Technology development	0.258	3.154	2.576	0.029	0.258																
7. Product	0.109	2.576	3.028	0.258	0.258	0.455															
8. Geographical	2.762	0.455	3.319	2.955	2.955	3.028	0.258														
9. Regulation changes 2	0.168	0.455	2.955	0.455	0.455	2.576	0.109	0.455													
10. Succession Planning	0.065	2.762	2.955	0.168	0.168	0.258	0.109	2.762	0.168												
11. Model complexity	0.168	3.093	2.955	0.455	0.455	2.576	0.258	2.955	0.455	0.168											
12. Convergence of Products	0.168	0.455	3.093	0.455	0.455	2.576	0.029	0.168	0.168	0.168	0.455										
13. Regulation changes 3	0.258	3.028	2.576	0.109	2.576	0.168	0.168	2.870	0.258	0.258	2.576	0.258									
14. Poor decision making	0.168	2.955	3.093	0.455	0.168	0.258	0.258	2.762	0.455	0.168	0.455	0.168	2.576								
15. Misunderstanding of risks	0.168	3.093	2.955	0.455	0.168	2.576	0.258	2.762	0.455	0.168	0.455	0.455	2.576	0.455							
16. HR policies	0.258	3.154	2.576	0.258	0.258	0.455	0.455	3.028	2.576	0.258	2.576	2.576	0.168	0.258	0.258						
17. Long-term planning	0.258	2.576	3.154	2.576	2.576	2.762	0.168	2.576	0.258	0.109	0.258	0.109	0.455	0.258	2.576	2.762					
18. Tech infrastructure	0.168	3.093	3.093	0.455	0.065	0.258	0.258	2.955	0.455	0.168	0.455	0.455	2.576	0.065	0.455	0.258	2.576				
19. Tax rules	0.168	0.455	3.093	0.455	0.455	2.576	0.029	0.455	0.168	0.168	0.455	0.065	0.258	0.455	0.455	2.576	0.258	0.455			
20. Regulation differences	0.168	0.455	3.093	0.455	0.455	2.576	0.029	0.168	0.168	0.168	0.455	0.065	0.258	0.455	0.455	2.576	0.258	0.455	0.065		
21. Tax management	0.065	2.762	2.955	0.168	0.168	0.258	0.029	0.455	0.168	0.065	0.168	0.065	0.258	0.168	0.168	0.258	0.258	0.168	0.065	0.065	
22. Infrastructure	0.168	3.093	3.093	0.455	0.065	0.258	0.258	2.955	0.455	0.168	0.455	0.455	2.576	0.065	0.455	0.258	2.576	0.000	0.455	0.455	0.168

Key: Red indicates risks are closely related, Green indicates risks are widely separated in evolutionary terms

Recap

- 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 a efficient way to classify and manage risks



Applications

- Any data with a large number of characteristics:
  - Classification of risk information
  - Anticipation of emerging risk possibilities
  - Analysis of organisation (e.g. Personnel skills, affinities)
  - Analysis of customer data
  - Analysis of business pipeline

The Actuarial Profession
making financial sense of the future

Uncertainty & Entropy

Finding the tipping point

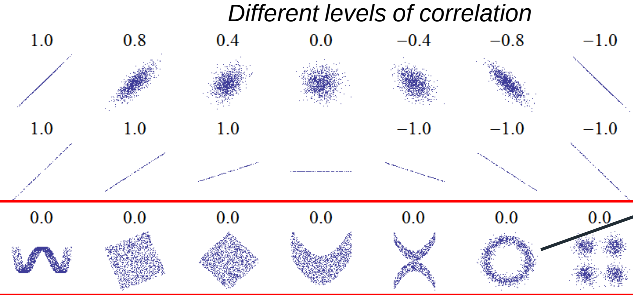
Entropy/Uncertainty

- Measuring the information content (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

Non-linear relationships

- Are we still talking?

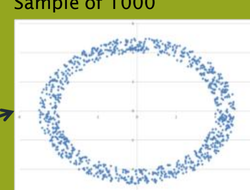
Different levels of correlation



Example

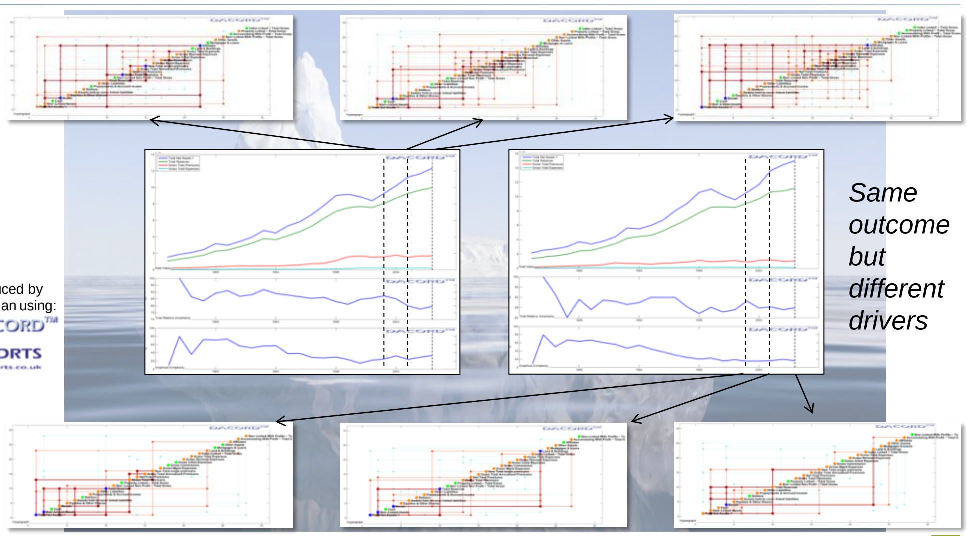
$\Theta \sim U[0,2\pi]$
$R \sim U[4, 5]$
$X = R \cos \Theta$
$Y = R \sin \Theta$

Sample of 1000



Correlation = 0.0
Mutual Info = 1.0

Looking beneath the surface



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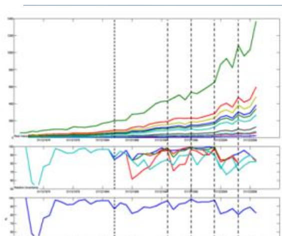
Same outcome but different drivers

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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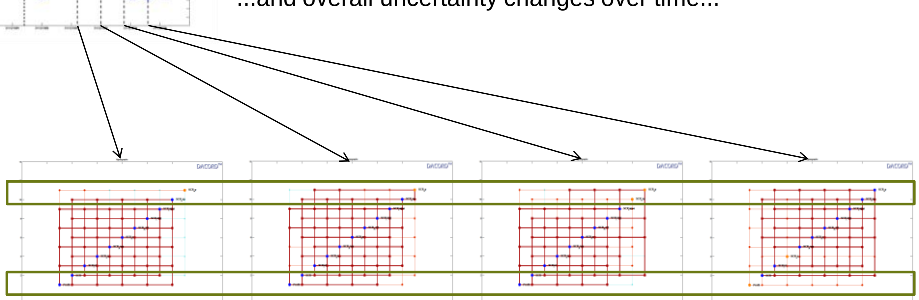


OpRisk gets more important

EqRisk gets less important

Applications

- Model-free complexity analysis can be applied to:
  - Risk monitoring – spotting early emerging risk signals
  - Business performance – signs of sluggish/out-performance
  - Business intelligence – factors affecting customers, markets
  - Understanding non-linear model outputs
  - Determining rating factors for risks

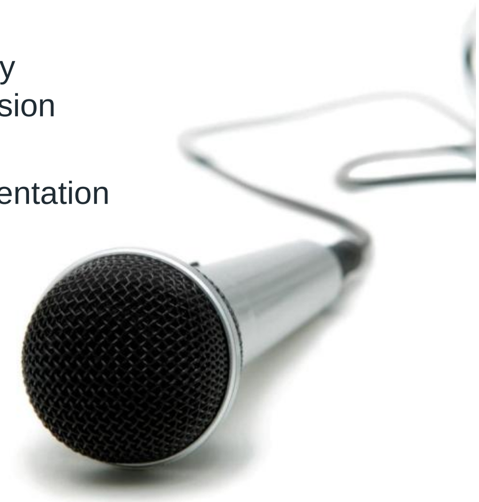
Summary

- We can frame companies/industries as complex adaptive systems
- Complex adaptive systems give out signals
- Using the right scientific tools you can spot them
- Interactions are the important part
- Early warnings are possible
- Don't throw away information – look for patterns
- Try not to guess what is going on before you look at the data
- Evolution is informative about possible future trends
- Improved understanding facilitates better models/management

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 presenters.



Characteristics of simple, complex systems and complex adaptive systems

Simple systems	Complex systems	Complex adaptive systems
Have predictable behaviour; e.g. a fixed interest bank account.	Generate counter-intuitive behaviour that is full of surprises; e.g. lower taxes and interest rates leading to higher unemployment.	The elements of a system can change themselves (this relates to notions of autonomy).
Few interactions and feedback or feed forward loops; e.g. a simple barter economy with few goods and services.	A large array of variables with many interactions, lags, feedback loops and feed forward loops, which create the possibility that new, self-organizing behaviours will emerge; e.g. most large organizations, life itself.	Complex outcomes can emerge from a few simple rules (this relates to initial starting conditions and the idea that complicated targets and plans may stifle creative and adaptive ability).
Centralized decision making; e.g. power is concentrated among a few decision makers.	Decentralized decision making – because power is more diffuse, the numerous components generate the actual system behaviour.	Small changes can have big effects and large changes may have no effect – i.e. non-linearity operates (e.g. in the UK a small band of lorry drivers interconnected by mobile phones almost brought the country to a standstill by blocking petrol deliveries to service stations).
Are decomposable because of weak interactions; i.e. it is possible to look at components without losing properties of the whole.	Are irreducible – neglecting any part of the process or severing any of the connections linking its parts usually destroys essential aspects of the system behaviour or structure. There are dynamic changes in the system and the environment.	Thrive on tension and paradox. (It is argued that healthy organizations exist on the edge of chaos – a region of moderate certainty and agreement).

(After Casti, 1994, pp.271–273 and Plsek 2001)