Complexity science approaches to the application foresight

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Abstract

Purpose – *This paper aims to present an exploration of recent work in complexity theory to explain why and how disruptive events happen in systems and how responses could be better, particularly in the policy-making arena.*

Design/methodology/approach – *The main method applied is critical thinking combined with a review of selected aspects of complexity theory and a general experience of applying foresight. Several new and practical implications for foresight techniques and their application are derived. Promoting variation is examined as one way to make policies more resilient in a complex system.*

Findings – *Complexity science demonstrates that disruptive events do not need an associated trigger, as they are a normal part of a complex system. This insight implies that if we are always looking for weak signals we will certainly be caught unawares.*

Practical implications – *The assumption that disruptive events can be managed by planning and forecasting is not a workable option. Instead, policy making needs to assume that unexpected disruptive events will happen even with the best horizon scanning system in place. Foresight techniques need to be developed to embrace emergence and to provide capabilities such as reframing to visualise systems from very different perspectives, including those considered impossible now.*

Originality/value – *Although neither complexity theory nor the concept of reframing is new in the area of foresight, the derivation of practical implications for foresight techniques is original.*

Keywords *Complexity, Disruptive events, Emergence, Reframing, Variation, Policy making, Complexity theory, Uncertainty management, Strategic planning*

Paper type *Conceptual paper*

1. Foresight techniques

To date, foresight techniques (see http://hsctoolkit.tribalhosting.net/The-tools.html for a summary of techniques, applications and case studies) have developed out of need (see www.andyhinesight.com/category/foresight-2/ (accessed August 2011) re practitioner usage); they are highly pragmatic, were originally developed for use in commercial organisations, and are used because they deliver useful insights However, other than some post-graduate foresight programs (provided on the basis that foresight is an interdisciplinary field grounded in a variety of social science), there has never been much underlying theory, or rationale, for either foresight or its techniques, Gheorghiou *et al.* (2008) and Miller (2011).

In many ways, foresight techniques also originally arose out of the need to deal with unexpected events in the technology and political arenas, for example the classic Shell scenarios. More recently the development of techniques for coping with disruptive events, often referred to as wild cards, has focussed on adapting scenario techniques, Ramírez and Van der Heijden (2008) or on wild card management, for example that based on weak signal methodologies, Mendonça *et al.* (2004). As complexity theory itself has developed, Mitchell (2009), so has some limited work in the foresight field, Ringland (2010) and Miller and Poli (2010), but there has been little specific consideration of how foresight techniques need to be developed more generally to accommodate complexity theory and its specific implications for disruptive events.

In addition, there has been little published work, or understanding, on how to really apply (implement) foresight and how to extract real value from the results of foresight studies and projects. Much foresight work, while very interesting and great fun to discuss over dinner, goes unused, unappreciated, and makes little observable difference. Foresight may be either an art or a science, Bell (2003), and may or may not be, a discipline, (or perhaps be developing into one), but either way, a critical thinking approach can be helpful. Bringing together complexity theory, reframing and some critical thinking provides a way to understand how techniques can work better, be applied better, and most importantly lead to better decision-making and policy making (and perhaps contribute to use of theories of social change in foresight).

2. Complexity

So what is complexity theory and what is its relevance to foresight? There are of course as many answers as people, including Prigogine and Stengers (1984), Byrne (1998) Mitchell (2009), Goodwin (1994), Strogatz(2003), and Waldrop (1992), but like any developing area there are many common themes. This paper will explore some selected elements of complexity theory and their implications for foresight techniques, and later derive implications for the application of foresight in policy making.

There are five relevant elements of complex systems:

1. A system cannot be explained by breaking it down into its component parts because the key element is the interaction between the parts. The system needs to be considered as a whole. As a result of these interactions complex systems exhibit emergence – (self-organised) behaviour that results from these interactions. For example, consider taxies in a city. The location and availability of taxies in a city cannot be explained by breaking the system down into its individual parts – drivers, cars, customers, fares, other taxies etc. Rather it is an emergent property of the whole system resulting from the interaction between all the parts – the taxies and customers, the road system, the traffic (itself an emergent property of a city’s transport system), city taxi rules, and even the weather (the system environment):

   The implication is that foresight techniques must be able to embrace emergence and to focus on the idea of interactions rather than constituent parts. *Foresight techniques need to enable practitioners to develop a vision of a system’s emergent properties – the self-organised behaviour that could result from interactions between the parts.*

2. All systems have component agents (taxies, customers) and each agent in a system acts on its own set of *rules* and can be thought of as trying to get the ‘‘best’’ outcome for itself (best fare for the driver, lowest fare or fastest ride for the customer). The rules, which can be very simple (for example for a taxi driver they may be simply ‘‘1. Stop for any customer’’, and ‘‘2. Go wherever the customer wants’’) can lead to unexpected results (‘‘why are there no cabs around here today?’’). But the rules do not have to be fixed – they can change according changes in the system too (for a driver a late night in a bad area may change the first rule to ‘‘don’t stop for anyone’’). Rules can be laws and policies but also values and perspectives:

   The implication is that foresight techniques must be able to accommodate changes in the basic rules. *Foresight techniques need to enable a vision of changes in the essential profile of a system.*

3. The interactions between the component parts of a complex system (which include positive and negative feedback loops – no cabs on the street – ‘‘phone for one’’ or ‘‘take the bus’’) lead to non-linear relationships between ‘‘causes’’ and ‘‘effects’’. A ‘‘small’’ cause can have ‘‘large’’ effect, and a ‘‘large’’ cause a ‘‘small’’ (or no) effect. Systems are therefore not just very difficult to predict they are fundamentally impossible to predict.

Systems can also be unexpectedly very stable – highly resistant to change by policy intervention - or very unstable – such as where a policy intervention leads to stream of unexpected changes, perhaps in an unrelated area. For example a city's policy to increase the number of cabs available to go to the suburbs may have no effect or a policy to ensure clean cabs may simply result in cab drivers carrying around instant cleaning kits to use when challenged - and as a result letting their cabs get even dirtier between times. One way of visualising such non-linear relationships is as tipping points or phase changes – such as water freezing. Using the taxi example, phase change could result in ''no cabs for half an hour and then six come around the corner at once''. Not only does phase change happen very suddenly and over the whole system, but there are no early warning signals. Phase changes can occur in rules, expectations, behaviours, etc. Such phase change is increasing recognised as common in public policy; as organisational systems (people) adapt to the new environmental parameters (policies) the system can change radically, Ridgeway *et al.* (2000). Equally, there can be long periods of (apparent) stability, (called ''attractors'' as they are states to which the system is ''attracted'') which can which render policies utterly ineffective:

> The implication is that foresight techniques need to accommodate phase change situations, accepting that they will happen, and consider what ''phase-changed'' worlds might look like. *Foresight techniques need to enable visions of phase-changed worlds. Foresight techniques must also accept the likely absence of any early warning signals.*

4. Extreme sensitivity to initial conditions. The starting slate is never clean – extremely tiny errors in understanding where the system starts from can send any ''forecast'' off in totally the wrong direction. Using the taxi example, a driver's entire day may be determined by the first turn, left or right, made out of the parking space. An example from another area is an equation called the logistic equation. $f(x) = Rx(1 - x)$ is an apparently simple equation, but when iterated produces some incredible behaviour. The result diverges dramatically depending on the value of R – it bifurcates, with the line of the value taking one value or the other depending on the initial value of R. But it is exceedingly sensitive to the value of R; a difference in the 7th decimal place will determine which of two possible tracks it goes down Mitchell (2009):

> The implication is that foresight techniques need to recognise that a system has a critical history which can always influence the future; once any change has happened, a system cannot go back to where it was as the initial conditions have now changed. Failed policy cannot be repealed and things started again from scratch – it has already had an irreversible effect; a re-examination of the situation anew is required. *Foresight techniques need to recognise that everything is part of a system, that there is no ''new'' starting point, and that tiny, often trivial actions can have huge, irreversible, impacts.*

5. Non-equilibrium. Complex systems are not at equilibrium (if they are they are dead) and are always changing. Systems evolve, as do the agents, their rules and interactions – and the system plays out in a ''fitness landscape''. Imagine a landscape of mountains and valleys, where ''high'' is good for an agent (a performance measure) – an agent (taxi driver) aspires (has a strategy to) be on a high peak (making a big profit). But it is no good blindly climbing the nearest highest peak because it may not be a relatively high peak and to get to a really high peak you may first need to descend into a valley. In other words, by blindly climbing the nearest highest peak (the current optimum) an agent may get stuck there while others climb higher peaks. And in any case the landscape is not static and will change over time (and will never ''settle down'') – a peak may become worthless compared to others and the taxi driver may go out of business (selection). Therefore agents need to optimise their actions - to move or slide as the landscape changes but also explore the landscape far way to identify other options (objectives, strategies, and policies) and not cut off future options. But some of these options may not make any sense now – they may only do so as the landscape evolves and changes (using the taxies example customers may decide to share taxies to different destinations as the norm).

Agents need to be able to see the adjacent deep valley a potential future peak, or recognise that a peak where they are now is in fact low compared to others. Evolution-type strategies are often used in a fitness landscape, which means that a balance of optimisation and exploration is required:

> The implication is that foresight techniques must be able to provide both optimisation and exploration processes to help identify a range of potential future situations and options. They must also enable acceptance that some options will sound negative or ludicrous now (for example descending initially into a profit-free valley now in order to access higher peaks). *Foresight techniques need to enable practitioners to see the landscape from different perspectives and to generate both optimum and (currently) non-optimum alternative potential strategies and options.*

In short, complexity can be summed up in the simple phrase, ''the whole is more than the sum of the parts''. Several authors have developed concise descriptions of complex systems incorporating most of the concepts considered above. It is worth considering these different definitions before looking in more detail at how complexity can contribute to improved foresight application.

Glouberman and Zimmerman (2002) A complex system is made up of many individual, self-organizing elements capable of responding to others and to their environment. The entire system can be seen as a network of relationships and interactions, in which the whole is very much more than the sum of the parts. A change in any part of the system, even in a single element, produces reactions and changes in associated elements and the environment. Therefore, the effects of any one intervention in the system cannot be predicted with complete accuracy, because the system is always responding and adapting to changes and the actions of individuals.

Mikulecky (2001) Complexity is the property of a real world system that is manifest in the inability of any one formalism being adequate to capture all its properties. It requires that we find distinctly different ways of interacting with systems. Distinctly different in the sense that when we make successful models, the formal systems needed to describe each distinct aspect are not derivable from each other.

Axelrod and Cohen (2001) A complex system is a body of causal processes and agents whose interactions lead to outcomes that are unpredictable. So the interactions among agents often have unpredictable consequences and the agents themselves adapt their behaviour based on past experiences: they interact in intricate ways that continually reshape their collective future.

From a foresight perspective however, Axelrod's (1985) is the most useful:

> Agents, of a variety of types, use their strategies, in patterned interaction, with each other and with artefacts. Performance measures on the resulting events drive the selection of agents and/or strategies through processes of error-prone copying and recombination, thus changing the frequencies of the types within the system.

The taxi example can be easily explained in these terms, Table I; a flock of birds flying is another, Reynolds (1987).

In summary the implications of complexity theory for foresight techniques are that they must:

- Enable a vision of a system's emergent properties.
- Embrace emergence rather than planning and forecasting.
- Focus on interactions rather than constituent parts.
- Recognise that even the basic rules and essential profile of a system can change (where rules can be laws and policies, but also values and perspectives).
- Enable visioning of phase change situations (with no early warning signals) and the resulting changed world.
- Recognise that everything is part of a system where tiny, trivial actions can have huge, irreversible impacts.

Table I Examples of components in a complex system

Element	*Example – Taxis in a city*	*Example – Flying flock of birds*
Agents . . .	Taxi drivers, and their customers) . . .	Birds in a flock
. . . of a variety of types	Experienced, new, night, cheating	Experienced, young, male, female, hungry
. . . use their strategies (rules)...	1 Minimise time to find customer 2 Go where customer wants	1 Avoid crowding neighbours 2 Steer towards the average heading of neighbours 3 Move toward the average position of neighbours
. . . in patterned interaction, with each other...	Customer directs driver, pays driver. Driver drives customer to location	Fly together to a certain location without crashing
. . . and with artefacts. . .	Money, cars, phones	Wind, wings
Performance measures on the resulting events . . .	Profit made, car undamaged	Obstacle not hit, bird stays with the flock
. . . drive the selection of agents and/or strategies...	Drivers who don't make enough profit go out of business Taxies that are damaged reduce drivers' profits	Die if hit an obstacle Get eaten by predator if lose the flock
. . . through processes of error-prone copying and recombination . . .	Try out strategies of other successful drivers – jumping lights, cleaning taxi	Try out strategies to get to best food-position in flock – fly faster, slower
. . . changing the frequencies of the types within the system	More successful drivers, fewer new drivers, more cleaner taxies	More faster birds, angry birds

- Enable practitioners to visualise systems from very different perspectives, including ones not possible now, and to generate an understanding of these different perspectives on potential policy options.
- Enable the generation of a range of future options and alternative potential strategies through both optimisation and exploration, including some that sound negative, impossible or ludicrous now.

3. Improving foresight application – reframing

One way to think of all of these ideas together is as different ways of seeing, of being conscious and aware about the nature of the mental model, i.e. being a description of perception rather than a description of reality (Schwartz, 1991), or more simply as reframing the future landscape and potential strategies, options, and potential policies. In general we are trained to think in terms of linear causality; doing anything else is difficult, disturbing, and different. Complexity theory can provide a newer way of looking at change and shows why reframing becomes important. Whatever we say about the future has an implicit idea of change underlying any inference and most theories of social change have an underlying implied pattern, although we are not always aware of it. And while no theory explains everything, complexity potentially offers us the closest we have ever come to having an overall theory of social change.

In simple terms Reframing is:

- changing the way you think;
- changing the way you see things;
- changing the way you understand things;
- not trying to solve problems using the same frame they emerged from;
- generating new solutions to issues; and
- enabling alternative actions.

An example of Reframing from Battram (2000): After much searching in many different areas of the city, you have finally found a possible flat to buy and you go for a walk to explore the area a little more. You pass a newsagent and decide to drop in for a newspaper and some chocolate. You pay and take your purchases but the newsagent gives you too much change.

You realise, keep quiet and start to walk out of the shop; no-one will know. . . But then you think . . . I may buy the flat, I may be coming here again, the owner will know who I am. You turn round and return the excess change.

By simply thinking about a possible future (the purchase of the flat), you have changed your frame. And you have changed your opinion and even changed your actions. Axelrod and Cohen (2001) call it the ''shadow of the future''.

From the perspective of applying foresight the benefits of reframing are:

- realising that there are more choices than thought, and that those possibilities can be created;
- bringing something new into existence;
- creating something outside the cone of possibilities;
- deconstructing an existing frame to explain or demonstrate to others that they are stuck in one frame; and
- an ability to deliberately switch frames.

In addition to using Reframing to enable a change in the way we see, think about, and understand things, we are often utterly unaware of how our ways of seeing are driven and constrained by our values. When unrecognized and unexamined, our preferences often pass for objective assessments of plausibility and probability; ''Impossible is just and opinion''. Some foresight techniques do use Reframing, for example in causal layered analysis, Inayatullah (1990), employs reframing at the deep myth/metaphor level.

4. Results – policy making implications

We all have our favourite story of a failed or ludicrous policy where a lack of foresight is obvious – in retrospect. The lesson is often that the environment/time/space/area in which one works and lives in determines how one thinks (the mental model or frame), and not only is it difficult to get out of that ''thought channelling'' process, but one is usually not even aware that thoughts are being channelled.

The key insight of complexity-based foresight for policy making is that command and control approaches do not work in complex systems. The resulting implication is that a system cannot be controlled from ''above'' and so policy operating in a complex system cannot achieve a specific outcome directly. Instead, policy making needs to embrace emergence – to exploit the developing behaviour that results from interactions between the parts of a complex system; specifically policy makers must focus on the idea of interactions rather than a system's constituent parts and develop a vision of the self-organised behaviour that could result from interactions between the parts.

What does ''embracing emergence'' actually mean? There are different ways of understanding the idea and what it may mean for policy making. For example, emergence is a process of change and embracing it can mean choosing to respond, continuously, to that change, sympathetically and synergistically rather than a controlling, combative style: embracing not resisting. Another way is to accept that change is the force of control rather than being the result of controlling intentions. In this case, embracing emergence can mean supporting and encouraging the current situation, and its emergent change, in a way that ensures that generally desirable outcomes will thrive, irrespective of what those specific outcomes might be. It could also be about accepting that it is the route being travelled, rather than the unknowable destination, that matters, particularly when that route is uncertain.

What then could embracing emergence mean for policy making? Simplistically, it is about understanding the system, in terms of a system's interactions rather than its component parts, so that policy is designed to stimulate evolution rather than to force control. Such policy making requires iterative monitoring of the emerging changes, to ensure that the desirable ones are supported and the undesirable ones diverted. Axelrod and Cohen (2001) describe the idea of harnessing complexity – to deliberately change the structure of the system, and to do so by changing the way in which a system is perceived – use of different mental models, or reframing. Again, policy makers need to watch for the ''emergent'' properties that arise as a system organises itself following a policy intervention, and use that policy to preserve the conditions in which the best solutions arise. With these perspectives, the link with, and importance of, the concepts of optimisation and exploration (resulting from the non-equilibrium state of a complex system – see section 2.5 above) also becomes clearer. The activities of embracing emergence, stimulating evolution, and harnessing the system, can all enable policy makers to see the system from a different perspective and to generate both optimum and (currently) non-optimum alternative potential strategies and options.

In terms of policy making, ''embracing emergence'' can be seen as very different to many FTA techniques. Horizon scanning for example focuses is on the possible results and outcomes (futures) resulting from a change process, rather than working with(in) interactions of the systems components itself. Similarly with techniques such as trend or driver analysis, and even scenario development, the onus is on a vision of the final outcome, and policy options for that final outcome, rather than on a vision of the self-organised behaviour that could result from interactions between the components, and how that can be harnessed.

Some writers, Battram (2000) and Swanson and Bhadwal (2009), have considered how complexity-based foresight can be applied to policy making. For example looking for shorter term, finer grained measure of success that can usefully stand in for longer-run, broad goals, ''trying it on and see what you get'', and using social activity to support the growth and spread of value criteria. Other methods include observing patterns, relationships, and rhythms rather than events (a specific example of focusing on interactions rather than constituent parts of a system), promoting effective neighbourhoods, building networks of reciprocal interaction, and promoting variation.

Much as it might be interesting and intellectually satisfying to re-invent the whole policy making process in the light of complexity-based foresight, the current (and historic) general policy making environment is likely to be the one in which implications for the application of complexity-based foresight in policy making will take place, at least for a while. We will therefore use a simple, generic, policy-making model, Table II adapted from Bhimji (2009) - direction, design, and delivery – to explore one example of a complexity-based technique to deal with disruptive events in policy-making – Promoting variation.

Promoting variation can provide a response to several of the requirements of foresight techniques identified above in Section 2. For example it can contribute to generating a range of future options and alternative potential strategies through both optimisation and exploration. Promoting variation can also contribute to embracing emergence and to enabling visions of phase change situations. In this case promoting variation also constitutes a risk management approach, whereby a policy is more able to work as its environment changes – while many of the policy interventions will fail (and failures are a normal feature of complex systems) having several options increases the likelihood that at least one option will succeed.

Promoting variation in practical policy making terms can mean using several options to achieve an intended outcome as implementing a variety of policies to address the same issue increases the likelihood of achieving desired outcomes. In this case, reframing can

Table II A simple policy making model

Policy direction → *Objectives*	*Policy design →* *Objectives*	*Policy delivery* *Objectives*
Discover new policy problems or opportunities Scope or define a policy area and determine a vision	Identify policy options Test policy options	Implement policy Monitor policy

Source: Adapted from Bhimji (2009)

bring the benefits of realising that there are more variations than originally thought of and of creating something outside the original cone of possibilities. But promoting variation can also be viewed as a set of ''parallel experiments'' being undertaken simultaneously with the aim of achieving a common objective. Here, reframing can bring several benefits. For example, providing an awareness of existing frames and ways of seeing, demonstration that those ways of seeing are driven and constrained by particular values or expectations, and being able to deconstruct an existing frame to demonstrate that a particular way of seeing is being used. In addition, reframing enables deliberate switching between frames to generate new experiment variations and options.

There are at least three key ideas, Battram (2000) and Swanson and Bhadwal (2009), which can help policy makers to promote variation:

1. Specifically promote variation by designing and implementing a range of alternative policy options to meet the various needs of different stakeholders. Using a mix of policy instruments, exploring synergies with other policies, providing opportunities for risk-spreading, and undertaking cost-benefit analysis.
2. Create an enabling environment for variation by facilitating conditions that enable societies to create alternative approaches to achieve a common objective or to respond to a common issue. Identifying influencing factors and removing barriers to facilitating variation.
3. Study from past and current experiences and adapt as needed by reviewing what policy interventions would usefully create or destroy variety and considering if the variety that results can offer potential value. Considering alternative sources of variety which could have greater promise and arranging organisational routines to generate a good balance between exploration and exploitation options.

Table III shows how promoting variation can be applied in practice at each stage of the simplified policy making process:

5. Conclusions

Complexity theory can provide a different perspective on how and why future disruptive changes may happen in a system. It also provides insight into how foresight techniques need to be developed to perform better in complex systems to enable better decision-making and policy making.

Table III Implementation of promoting variation in policy making

Policy direction	*Policy design*	*Policy delivery*
Discover new policy problems or opportunities	Identify policy options	Implement policy
Scope or define a policy area and determine visions	Test policy options	Monitor policy
1. Understand the varied expertise and resources are required to generate different visions	1. Create and enable an environment for variation to occur	1. Comparative analysis of the costs of implementation and benefits accrued for each policy option
2. Encourage the adoption and deployment of these different visions through appropriate policies to minimize risks	2. Design and use a mix of policy instruments to achieve a single policy objective	2. Review of the efficiency of the policy options as newer conditions unfold and emerge
3. Identify and characterise the potential risks of the different visions	3. Provide a range of policy options	3. Monitor and evaluate the policy instruments deployed to promote variation
4. Identify alternative policy options that can minimize the impacts from the any identified risks	4. Remove the barriers that hinder the adoption of these strategies	4. Incorporate feedback from the ''grassroots'' level where variation needs to be promoted
5. Reframing and similar techniques can be used	5. See and make linkages with other policies that have similar intent	5. Observe which policies work well and strengthen those policies

Foresight methodology

Foresight techniques need to be developed to embrace emergence – to harness the self-organised behaviour that results from interactions between the parts of a complex system – rather than rely on external planning and forecasting. They should enable visioning of phase change situations (with no early warning signals) and the resulting changed world. In particular they need to provide methods and skills (such as reframing) to visualise systems from very different perspectives including ones that are not considered possible now, and to enable users to develop an understanding of implications these different perspectives on potential policy options. Foresight techniques must provide policy makers with the ability to generate a range of future options and alternative potential strategies through both optimisation and exploration, including some that sound negative, impossible or ludicrous now.

Policy making

In a complex system (which all societies are) policy makers need to recognise that systems are all about relationships and interactions between the constituent parts rather than about the details of the constituent parts. Policy makers need to be very comfortable with the fact that emergence and phase change are normal and therefore that prediction and forecasts do not work well in complex systems. They must recognise that everything is part of the system, and that tiny, trivial actions can have huge, irreversible impacts. They must also recognise that even the most basic rules and the essential profile of a system can change, where the ''rules'' can be laws and policies, but also values and perspectives.

Policy making needs to take place with the knowledge that that disruptive events will happen and will be unexpected, even with the best horizon scanning system in place. Policy making needs foresight techniques to enable a vision of the system's emergent properties and also of phase change situations (without early warning signals) and of the resulting changed world. Policy making must use techniques such as Reframing to visualise systems from very different perspectives, including ones not possible now, and to understand the implications of these different perspectives on potential policy options. Policy making needs Foresight techniques to enable the generation of a range of future options and alternative potential strategies through both optimisation and exploration, including some that sound negative, ludicrous, or even impossible today.

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