THIS PAPER WILL BE PUBLISHED AS CHAPTER 3 IN 'SYSTEMS ENGINEERING FOR BUSINESS PROCESS CHANGE', EDITED BY PROFESSOR PETER HENDERSON, PUBLISHED BY SPRINGER-VERLAG, ISBN-1-85233-222-0

COMPLEXITY: PARTIAL SUPPORT FOR BPR?

Eve Mitleton-Kelly

Director, Complexity Research Programme, London School of Economics

Abstract

If organisations can be said to thrive and become more innovative when pushed far-from-equilibrium [5,7], then Business Process Re-engineering may be seen as a means of creating these conditions. However, BPR often disregards the consequences of massive disruption in connectivity and tends to restrict emergence and self-organisation. The new *engineered* or *designed* structure may provide a new framework, but it does not encourage exploration, learning and evolution. Neither does it support divergence and variety, which are essential elements in enabling the emergence of new behaviours and ways of working. BPR, by relying on designing and controlling both the process and the outcome, blocks emergence and thus disables one of its key objectives. The creation of a new way of working.

The paper will propose three ways of looking at complexity and show how two of them may support BPR. But will also argue that BPR ignores the third way of looking at complexity and does not support the principles of *emergence*, *co-evolution*, and *exploration of the space of possibilities*. Some of the generic characteristics of complex adaptive systems will be outlined and related to social systems and to interventions such as BPR.

This is an exercise in the exploration of concepts and ideas, and is not based on field research. The paper is taking some of the principles that are emerging in the study of complex social systems and is thinking through some possible applications and implications when an intervention such as BPR is introduced in an organisation.

1. The Theories of Complexity

There is no single Theory of Complexity, but several theories arising from the various sciences of complexity, such as biology, chemistry, computer simulation, evolution, mathematics and physics. The work referred to will be that undertaken over the past three decades by scientists associated with the Santa Fe Institute in New Mexico, and particularly that of Stuart Kauffman [1,2] and John Holland [3,4] on complex adaptive systems (CAS), as well as the work of scientists based in Europe, such as Prigogine [5,6,7], Stengers [5], Nicolis [7,8], Allen [9] and Goodwin [10,11].

By contrast, very little research has been undertaken in complexity within social systems. Some work has been done on economics, particularly by Brian Arthur [12,13] and Geoff Hodgson [14], but the research and published material on strategy and organisational complexity is limited to a few papers and a handful of books by Stacey [15, 16, 17], Parker 15,18] Lane [19] and McMaster [20].

2. What is Complexity?

2.1 Connectivity

Complexity arises from the inter-relationship, inter-action and inter-connectivity of elements within a system and between a system and its environment. Murray Gell-Mann [22] traces the meaning to the root of the word. *Plexus* means braided or entwined, from which is derived *complexus* meaning braided together, and the English word "complex" is derived from the Latin. Complexity is therefore associated with the intricate inter-twining or inter-connectivity of elements within a system and between a system and its environment.

In a human system, connectivity means that a decision or action by any individual (group, organisation, institution or human system) will affect all other related individuals and systems. That affect will not have equal or uniform impact, and will vary with the *state* of each related individual and system, at the time. The state of an individual and system will include its history and its constitution, which in turn will include its organisation and structure. Connectivity applies to the inter-relatedness of individuals *within* a system, as well as to the relatedness *between* human social systems, which include systems of artifacts such as information technology (IT) systems and intellectual systems of ideas.

The term 'complexity' will be used within this paper to refer to the theories of complexity as applied to complex adaptive systems (CAS). These are dynamic systems able to adapt and change within, or as part of, a changing environment. It is important however to note that there is *no dichotomy between a system and its environment* in the sense that a system always *adapts to* a changing environment. The notion to be explored is rather that of a system *closely linked with* all other related systems making up an ecosystem. Within such a context change needs to be seen in terms of *co-evolution with* all other related systems, rather than as *adaptation to* a separate and distinct environment. Human systems will be referred to as complex social systems (CSS) to distinguish them from all other complex systems.

When a business is radically re-engineered or re-designed, both the *internal connectivity* within the organisation, as well as the *external connectivity* between the business and its related businesses will be affected. If each business process is seen as a co-evolving *social ecosystem* nested within wider social ecosystems, then re-design gains a totally different perspective. Furthermore, inter-related elements within and between systems have varying degrees of dependence. Consequently, when a change or intervention is introduced in any one part, the effect of that change or intervention may have significant or minor consequences in many other parts of the system. As each element attempts to adjust to the intervention, it is affecting the entire social ecosystem, and is in turn being influenced by the changes in the social ecosystem.

The system is *co-evolving with* its ecosystem and both are changing. But the *degree* and the *nature* of the changes within the social ecosystem (at all scales) are unpredictable. Hence using the language of precision implied in the term 're-engineering' is totally misleading. There can be no precision or control either of the degree or the nature of change.

For example, when one entity tries to improve its fitness or position this may result in a worsening condition for others. Each 'improvement' therefore may have associated 'costs' on other entities, either within the same system or on other related systems. The greater the dependence between related systems or entities the greater the perturbation or disturbance of a move or action by any one entity on all the other related entities. A high degree of dependence rarely has beneficial effects throughout the ecosystem.

Degree of connectivity is also associated with the quantity and quality of information, which flows between the connected entities. When businesses are re-engineered the flows of information are directly affected. In the early stages of transition between the old and new regimes, connectivity is disrupted and individuals no longer know whom to approach for information. It is worth noting that the informal social and information network is disrupted much more fundamentally than the formal. Designers tend to concentrate on re-designing the formal network of information exchange and tend to ignore the informal network, which is often the more effective means of accessing information and of 'getting things done'.

2.2 Far-from-equilibrium & dissipative structures

One way of looking at complex systems is as dissipative structures, which are open systems exchanging energy, matter or information with their environment. The study of dissipative structures, provides a view of how systems transform themselves.

In Prigoginian terms [5,6,7], all systems contain subsystems which are continually *"fluctuating"*. When one or more fluctuations become so powerful, as a result of positive feedback, that they shatter the pre-existing organisation, the system has been forced into a *far-from-equilibrium* condition and has reached a point of *bifurcation*.

It is inherently impossible to determine in advance which direction change will take.

The system may disintegrate into instability or leap to a *new level of order* or organisation called a *"dissipative structure"*. It is given that name because it requires more energy (or information) to sustain it than the simpler structure it replaced, and because it expels or dissipates useless energy (heat, noise, etc).

In terms of the flow of information, a stable system can be sustained with a sluggish flow, but a much more vigorous and richer flow is necessary for a system operating far-from-equilibrium. If the flow of information becomes too fast, however, then the system may disintegrate.

Prigogine and Nicolis [7] have shown that when a physical or chemical system is pushed *away from equilibrium*, it survives and thrives while if it remains at equilibrium it dies. The reason is that when far-from-equilibrium, systems are forced to experiment and explore their *space of possibilities* and this exploration helps them discover and create new patterns of relationships and different structures.

If this characteristic were to apply to individuals and to social systems, then when an individual or a system is pushed either by circumstances or deliberate intervention away from an established pattern of behaviour, or when constraints are encountered in reaching a desired goal, then humans are forced to experiment, to explore their space of possibilities and to find alternative ways of attaining a goal or changing the goal altogether. They find new patterns of relationships, different structures and innovative ways of working.

But this is only one aspect of the argument. For if a systems is pushed too far away from a stable state, it may become totally unstable.

2.3 Edge of Chaos Paradox

The notions of stability and instability provide a third way of looking at complexity. This view is closely associated with chaos theory and sees complexity in terms of emergent order co-existing with disorder at the *edge of chaos*. When a system moves from a state of order towards increasing disorder, it goes through a transition phase called the edge of chaos. In that transition phase new patterns of order emerge among the disorder and this gives rise to the paradox of order co-existing with disorder. Complexity in this view is seen in terms of *the order which emerges from disorder*.

All three, are valid ways of thinking about complexity, that is in terms of *interconnectivity, as dissipative structures* and as the *edge of chaos paradox.*

3. Chaos and Complexity

Although chaos and complexity are at times used interchangeably, they are not identical and need to be distinguished as their application to social systems may differ. Chaos theory or non-linear dynamics is based on the *iteration* either of a mathematical algorithm or a set of simple rules of interaction. It provides some powerful analogies associated with the edge of chaos, the emergence of order, and the co-existence of stability and instability. *Iteration* is defined by Brian Goodwin as the “emergent order (which) arises through cycles of iteration in which a pattern of activity, defined by rules or regularities, is repeated over and over again, giving rise to coherent order.” [23] But, in chaos theory the iterated formula remains constant, while *complex systems are capable of evolving* and of changing the ‘rules’ of interaction. When applying chaos theory to human systems, the analogy becomes inappropriate and misleading. Humans are not mathematical algorithms, they have cognitive faculties which enable them to change their rules of interaction.

Analogies from chaos theory have frequently been misapplied and this paper will restrict the application of such analogies to a partial explanation of the emergence of new patterns when a system is operating on the 'edge of chaos'. Chaos theory and complexity may share certain characteristics but differ in so far as a complex adaptive system is able to *evolve* and change. For the purposes of this paper chaos theory will be used to refer to a limited application of systems subject to the iteration of 'defined rules and regularities'.

3.1 And social systems

The distinction between chaos and complexity is particularly important when considering the application of the principles or characteristics of chaotic or complex systems to social systems. Principles or properties, which are based on chaos theory and apply to chaotic systems, need to be applied with great circumspection to social systems, and only as weak metaphors or analogies.

This paper will take a different viewpoint and suggest that social systems are fundamentally different from all other complex systems. That does not mean that all the valuable work achieved by the sciences of complexity is disregarded. For that would be myopic insularity. On the contrary. Such work needs to be studied as it can provide a significant *starting point* for the study of complex social systems. What must be *avoided* is the *mapping* of principles from the natural sciences onto social systems. Such an attempt would be inappropriate, as the subject matter of different disciplines is constituted in a different way and is based on different units of analysis (e.g. molecules, species, individual humans, societies, etc.). Mapping would also assume similarities between those systems studied by the natural and social sciences, which may not exist, and which could lead to an ontological category mistake.

Although the paper assumes that there is a fundamental distinction between human and other complex adaptive systems (CAS) based on the assumption that human systems are made up of *conscious* individuals *aware* of and *capable* of making a choice, there is a strong argument against that distinction. The counter argument posits the view that in the aggregate, social systems are not different from all other CAS and individual human choice can be discounted as it does not significantly influence the outcome of a system as a whole.

It may also be argued that physical, chemical and biological systems are *not conscious* and do not 'learn' in the sense that humans learn. But here the argument is weak. We may agree that individual humans do learn and are able to change their behaviour through conscious choice, an option not open to physical, chemical or biological elements. Yet elements and organisms do adapt. Is adaptation not a form of 'learning'? Furthermore, do organisations or societies learn in the aggregate? Are we not reifying or mentally converting a collection of individuals into a 'thing' with the properties of those individuals? Are social systems, as distinct from individual humans, able to learn? Are they fundamentally different from other CAS, just because their individual elements are different?

The question is raised to draw our attention to the nature of social systems - to the features that make them different from all other CAS - and to the dangers of mapping theories from other domains. The nature of social systems needs further discussion in a different milieu. For the purposes of this paper, it will simply be proposed that human systems are fundamentally different from other complex systems and that chaos theory should only be applied as metaphor or analogy. To emphasise that distinction, human systems will be referred to as complex social systems (CSS).

Taking all the above into consideration, and focussing on organisational complexity, the following working definition is proposed.

Organisational complexity *is associated with the intricate inter-relationships of individuals, of individuals with artifacts (such as IT) and with ideas, and with the effects of inter-actions within the organisation, as well as between institutions within a social ecosystem. Complexity arises through connectivity and the processes of feedback and emergence.*

Complexity is not a methodology or set of tools. It certainly is not a 'management fad'. The **theories of complexity** provide a conceptual framework, **a way of thinking** and **a way of seeing the world**. They also provide a different explanation of how the world is, which is different from the Newtonian and Cartesian paradigms.

4. Complexity and BPR

Using the dissipative structure terminology, BPR may be said to provide the conditions, which push an organisation into a far-from-equilibrium condition. Seen from a chaos theory perspective, BPR attempts to move the system towards the 'edge of chaos'. As a dissipative structure, the emphasis is placed on the energy or information required and dissipated by the system; while the transition phase between stability and instability at the edge of chaos places the emphasis on the new patterns of order which emerge among, and co-exist with, disorder. In both, complexity is seen in terms of new levels of *order which emerge from disorder*.

However, although complexity may, on the surface, provide some justification or support for BPR, this support is partial and ignores some of the fundamental principles of complexity. One of those fundamental principles is *connectivity*. When BPR radically restructures an organisation, it destroys connectivity in terms of the networks of communication and social inter-relations (fig. 1). But it also ignores the consequences of connectivity associated with interdependence. When a significant number of elements are disconnected or individuals are moved (or removed), the social network which supports both the formal and the informal organisational structure is disrupted. If the extent and affect of the disruption are not acknowledged, the means will not be provided to help re-establish the necessary new links and connections. It is perhaps the absence of supporting processes re-establishing the new connectivity, which is a fundamental weakness of BPR.

Fundamental restructuring

⇒ ***destroys connectivity***

of the networks of communication

and social inter-relations

The **social network** ***which supports both the formal and the informal organisational structure*** **is disrupted.**

If not acknowledged, the means will not be provided to help ***re-establish*** **the necessary** ***new links and connections*****.**

It is perhaps the ***absence of supporting processes re-establishing the new connectivity*** **which is a fundamental weakness of BPR.**

Figure 1 - Implications for BPR

Away-from-equilibrium

⇒ new relationships/connectivities

⇒ emergence of new patterns

⇓

new ways of working

⇓

new forms of organisation

Figure 2 - A Summary

To summarise, (fig. 2) BPR attempts to move an organisation away from equilibrium or from established patterns of work and behaviour. It intends to create new ways of working and to introduce new forms of organisation, but often fails because it does not provide the enabling framework for new relationships and connectivities to be established. Although the intention is to create new ways of working, it actually blocks or constrains emergent patterns of behaviour by attempting to design and control the outcome. If re-design were to concentrate on the provision of enabling infrastructures while allowing the new patterns of relationships and ways of working to emerge, new forms of organisation will arise which would be more attuned with the culture of the organisation. The new emergent organisation will thus be unique and not susceptible to copying. It will furthermore be more robust and sustainable.

5. *Procedure of study*

Although there is no single unified theory of complexity, there are certain *generic characteristics* or *principles*, which are *common to all natural complex systems.* One way of proceeding with the study will be to examine those *generic characteristics* and then to consider whether they are *relevant or appropriate to social systems*. But there are two conditions to that approach. One is to understand that such an examination is merely a starting point and not a mapping, and that social systems need to be studied in their own right as complex social systems. The other condition is that it is beyond the scope of this paper to examine all generic characteristics of complex systems and that only some of those, which are relevant or related to the subject under study, can be included.

6. Emergence and self-similarity

The terms used above have varied from 'element', to 'system' and to 'entity'. The use of language reflects one of the characteristics of complex systems, which is that similar characteristics apply at different scales. In an organisational context the generic characteristics of complex systems will apply *within* a firm at different levels (individual, team, corporate), as well as *between* related businesses and institutions which will include direct and indirect competitors, suppliers and customers, as well as the legal and economic systems. The term often used to describe the repetition of *self-similar* patterns across scale is *'fractal'* and is associated with chaos theory. The concept however also has certain similarities with the notion of *'hierarchy'* in systems theory. Hierarchy in this context does not refer to the vertical relationships of organisational structure or power, but to the notion of *nested subsystems.* But the interpretation of 'subsystem' differs between the two theories. A fractal element reflects and represents the characteristics of the whole in the sense that similar patterns of behaviour are found at different scales. While in systems theory, a subsystem is a *part* of the whole, as well as being a whole in its own right. It is "equivalent to system, but contained within a larger system." [24, p317]. The emphasis in systems theory is on the *wholeness* of the part rather than on the constitution or representative characteristics shown by that part. Checkland [24] makes that clear in his definition of hierarchy: "the principle according to which entities meaningfully treated as wholes are built up of smaller entities which are themselves wholes … and so on. In a hierarchy, *emergent properties* denote the levels.” [24, p314]

The concept of *emergence* which has been associated with systems theory, is also a fundamental characteristic of complex systems. In systems theory it is linked with the concept of the ‘whole’ – i.e. that a system needs to be studied as a complete and *interacting whole* rather than as an assembly of distinct and separate elements. Checkland [24] defines emergent properties as those exhibited by a human activity system “as a whole entity which derives from its component activities and their structure, but cannot be reduced to them.” [24, p314] The emphasis is on the *interacting whole* and the *non-reduction* of those properties to individual parts.

Another view of emergence is offered by Gregoire Nicolis [8] studying physical complex systems, who describes emergence in terms of self-organising phenomena. While Francisco Varela [26, 27], in his study of the human brain, sees emergence as the *transition* from *local* rules or principles of interaction between individual components or agents, to *global* principles or states encompassing the entire collection of agents.

Varela sees the transition from local to global rules of interaction occurring as a result of explicit principles such as *coherence* and *resonance*, which provide the local and global levels of analysis [26]. But adds that to understand emergence fully, we also need to understand the *process which enables that transition*.

The terms ‘fractal’ and ‘emergent property’ are often used as if they provided an explanation of what happens between levels of hierarchy or levels of scale, but the terms are *descriptive not explanatory*. Indeed, it is the *process of interaction* between the interconnected elements which brings forth or creates new patterns or emergent properties, but this is still a description and is as far as our understanding goes and it is not far enough.

Complexity researchers are attempting to understand the relationship between micro and macro behaviour and the properties within and between systems, and to explain the process of emergence [e.g. 4, plus others to be published].

6.1 BPR and Emergence

By attempting to control both the design criteria and the content of the process being re-designed, BPR is not allowing for emergence, self-organisation and learning. Neither does it support divergence and variety [28]. Both divergence and variety are essential elements in enabling the emergence of new patterns, or qualities, or behaviours or characteristics. By seeing divergence and variety as inefficiencies and replication to be designed out, BPR blocks emergence and deliberately disables one of its key objectives. The creation of a new way of working.

7. Co-evolution, fitness landscapes and exploration of the space of possibilities

One of the key characteristics of complex systems is that of the *co-evolution* of all related systems within an ecosystem. *"Co-evolution is a process of coupled, deforming landscapes where the adaptive moves of each entity alter the landscapes of its neighbors."* [29]. Complexity emphasises *evolution* <u>*with*</u> rather than *adaptation* <u>*to*</u> a changing environment and thus changes the perspective and the assumptions, which underlie traditional management and systems theories [30, 31].

When Kauffman refers to 'landscapes' he is referring to '*fitness landscapes*' which he has developed using the NK model [1, 29], where N stands for the number of entities or elements in a system and K stands for the degree of connectivity between the entities. Each entity N makes a fitness contribution which depends upon that entity and upon K other entities among the N. That is, K reflects the rich cross-coupling of the system and measures the richness of *epistatic interactions* among the components of the system.

The notion of epistatic interactions is used by geneticists to describe the process of coupling in which a new gene links into the network of a species' existing genes. In other words, the contribution which a new gene can make to the species' overall fitness depends on the existing genes of that species.

In social systems this may be likened to the history of experiences and constitution of an institution - new ideas can only be 'seen' and developed if both the constitution and the history allow them to be 'seen' and be developed [31].

A fitness landscape may also be used by companies to assess their 'fitness' within a competitive ecosystem [1, 32]. Such an exercise may be used to illustrate or clarify a number of issues: competitive fitness; conflicting constraints within a web of epistatically interacting entities; and participation within a co-evolving ecosystem. By changing different parameters, an organisation may take 'adaptive walks' within its industry 'landscape' – this would demonstrate the existing position as well as opening up other possibilities, which would improve its 'fitness' or competitive position. A fitness landscape would also demonstrate how each adaptive move affects the position of all other related businesses, how it 'deforms' the 'landscapes' of neighbours and would illustrate the concept of co-evolution.

In a co-evolving ecosystem, each organisation *is a fully participating agent which both influences and is influenced by,* the social ecosystem made up of all related businesses, consumers, economic and legislative institutions.

Change may be seen in terms of adaptive evolution. But adapting entities confront *conflicting constraints* both in their internal organization and in their interactions with their environments. These conflicting constraints typically imply that finding the 'optimal solution' is very difficult. But it also means that there may exist many alternative locally optimal solutions.

Furthermore, the consequence of attempting to optimise in systems with increasingly many conflicting constraints among the components brings about what Kauffman calls a ***'complexity catastrophe'***. As complexity increases, the heights of accessible peaks *recede towards the mean fitness*. The onset of the catastrophe traps entities on a local optimum and thus limits selection. This is clearly important. If this applies to organisations, what are the implications and how can this limitation be avoided?

Having to cope with increasing conflicting constraints is one problem associated with information technology. **"**These conflicting constraints typically imply that finding the "optimal solution" is very difficult and that many alternative locally optimal compromise solutions exist in the space of possibilities.....Technological evolution, like biological evolution, can be considered a search across a space of possibilities on complex, multi-peaked 'fitness', 'efficiency' or 'cost' landscapes." [29].

The development of IT systems is often a matter of accommodating conflicting constraints. It is highlighted in this paper because it forms an essential part of a re-designed business process.

Fitness landscapes explore the space of possibilities which includes change by mutation and by co-evolution. Mutation is an unpredicted 'step-change' as opposed to a gradual incremental change.

7.1 BPR, Co-evolution, fitness and the space of possibilities

BPR attempts to introduce a deliberate 'step-change' in order to improve the fitness landscape of the organisation. The notion of the fitness landscape is however intimately associated with co-evolution within an ecosystem. As an organisation attempts to alter its fitness landscape it directly affects the landscapes of all its related businesses and institutions. That is, a major intervention like BPR has significant impact both at the micro level within the organisation, as well as at the macro level of the social ecosystem.

Co-evolution is a process of mutual transformation. It is inextricably linked with the principles of connectivity and emergence and its development can neither be designed nor controlled to a fine degree. BPR, by contrast, relies on designing and controlling both the process and the detail. In doing so it blocks emergence, but it also restricts the exploration of the space of possibilities, by imposing a single 'optimum' solution. Complexity indicates that the search for a single 'optimum' strategy is neither possible nor desirable. The usual response following a major BPR re-structuring is the need and the time to establish the new routines and methods of working. People crave stability and a time of little change. They are consequently closed to the possibilities of 'seeing' new connections or 'exploring' different solutions. Furthermore, by downsizing, variety is ruthlessly reduced to the absolute minimum. Variety often means duplication or redundancy. Concepts which BPR tries to avoid, but which are essential in a complex evolving social system, to enable it to discover alternative solutions that will improve its fitness landscape.

8. Feedback and positive returns

Feedback is usually seen either as negative or positive. A familiar example of *negative* feedback is a central heating system. A thermostat monitors the temperature in the room, and when the temperature drops below that specified, an adjusting mechanism is set in motion, which turns the heating on until the required temperature is attained. Similarly, when the temperature rises above the set norm, the heating is switched off until the desired temperature is reached. The gap between the required and the actual temperature is thus closed. *Positive* feedback, on the other hand, would progressively widen the gap. Instead of reducing or canceling out the deviation, positive feedback would amplify it.

An example of positive feedback is the increasing lack of confidence in a company, which is believed to be in eminent collapse. The Board sees that demand for the product is declining and tries to improve the company's image and performance in the market place, through a series of internal re-organisations. But this mechanism has the opposite effect to that desired. It is so disruptive that good staff leave. This affects the relationships with clients, who no longer have contact with, and the advice of, knowledgeable representatives. In high-technology companies these relationships and the sense of confidence they engender is critical. A buyer will not commit company funds to a product that will not have technical support during its lifetime. As lack of confidence increases, sales of the product are adversely affected and a vicious circle of positive feedback sets in.

Arthur [12, 13] argues that conventional economic theory is also based on the assumption of negative feedback or diminishing returns, which leads to a predictable equilibrium point. Negative feedback has a stabilising effect, and implies a single equilibrium point, as "any major changes are offset by the very reactions they generate" [12, p92]. The example given, is the high oil prices of the 1970s, which encouraged energy conservation and increased oil exploration, precipitating a predictable drop in prices by the early 1980s. But, Arthur argues, such stabilising forces do not always operate. "Instead positive feedback *magnifies* the effects of small economic shifts", and increasing returns or *positive feedback makes for many possible equilibrium points*. Consequently, a particular outcome cannot be predicted.

8.1 BPR and Feedback

BPR relies on negative feedback and sees an organisation as a machine, which can be re-*engineered*. It talks of ‘mechanisms’, design and control. But ignores the possibility of positive feedback and increasing returns. Small changes in one part of the organisation may have significant and unforeseen consequences in another. Or, what might appear as minor changes in relationships, might have major consequences on the way work is done or on morale or on relationships with customers or suppliers or other related businesses.

9. Conclusion

1. The theories of complexity offer a way of *thinking*, a way of *'seeing'* the world.
2. Seen from a complexity perspective, BPR may provide the means to push an organisation to a far-from-equilibrium position, but tends to:

- Destroy connectivity
- Block emergence, self-organisation and learning
- Not acknowledge co-evolution
- Prevent the exploration of the space of possibilities
- Reduce variety and diversity

3. Apart from major restructuring, organisations need to consider change in terms of continuous *adaptation* and *evolution* by:

- learning how to recognise new emergent patterns
- co-evolving with other organisations

4. Need to develop a method of discourse - a *language* to talk about the new concepts. To develop and share their meaning.

Acknowledgements

The paper is based on research enabled by two EPSRC awards under the SEBPC Programme: IT & Computer Science Programme (GR/MO2590). The first one-year preliminary study of the two-phase project has been completed and the second 3-year project started in May 1998. The title for both projects is "The Implications of the Theories of Complexity for the Co-evolution of the Business Process and Information Systems Development".

Both projects explore the findings from the sciences of complexity and examine the implications of generic characteristics of complex systems for organisations. The focus of the second phase will be to develop tools, models and approaches, which will aid the co-evolution of the business process with, IS development.

REFERENCES

1. KAUFFMAN, S.: 'The Origins of Order: Self-Organisation and Selection in Evolution' (Oxford University Press, 1993)

2. KAUFFMAN, S.:'At Home in the Universe' (Viking, 1995)

3. HOLLAND, J.: 'Hidden Order: How Adaptation Builds Complexity' (Addision Wesley, 1995)

4. HOLLAND, J.: 'Emergence: From Chaos to Order' (Addison Wesley, 1998)

5. PRIGOGINE, I. & **STENGERS,** I.: 'Order Out of Chaos' (Flamingo, 1985)

6. PRIGOGINE, I.: 'Time and the Problem of the two Cultures', First International Dialogue on the transition to Global society, Landegg Academy, September 3-9 1990

7. NICOLIS, G. and **PRIGOGINE** I.: 'Exploring Complexity' (WH Freeman, 1989)

8. NICOLIS, G.: 'Physics of far-from-equilibrium systems and self-organisation' Chapter 11 in 'The New Physics' ed. by **DAVIES**, P. (Cambridge University Press, 1989) (reprinted 1994)

9. ALLEN, P.M.: 'Cities & Regions As Self-Organizing Systems : Model of Complexity' Environmental Problems & Social Dynamics Series, Vol 1, (Gordon & Breach Science Pub; 1997)

10. GOODWIN, B.: 'How the Leopard Changed Its Spots' (Phoenix, 1995)

11. WEBSTER, G. & **GOODWIN**, B.: 'Form and Transformation: Generative and Relational Principles in Biology' (Cambridge University Press, 1996)

12. ARTHUR, B.W.: 'Positive Feedbacks in the Economy' Scientific American, February 1990

13. ARTHUR, B.W.: 'Increasing Returns and Path Dependence in the Economy' (Michigan, 1995)

14. HODGSON, G.M.: 'Economics and Evolution: Bringing Life Back Into Economics' (Polity Press1993)

15. PARKER, D. & **STACEY**, R.D.: 'Chaos, Management and Economics: the Implications of Non-Linear Thinking' Hobart Paper 125, 1994, Institute of Economic Affairs,

16. STACEY, R.D.: 'The Science of Complexity: An Alternative Perspective for Strategic Change Processes' in Strategic Management Journal, Sept 1995, Vol 16, No 6, pp. 477-495

17. STACEY, R.D.: 'Complexity and Creativity in Organizations' (Berrett-Koehler, 1996)

18. PARKER, D.: 'Nonlinear Dynamics and Organisational Adaptability' Research Paper, April 1995

19. LANE, D.A. & **MAXFIELD, R.: '**Foresight, Complexity and Strategy', in 'The Economy As an Evolving Complex System II : Proceedings' 1997, (Santa Fe Institute Studies in the Sciences of Complexity, Vol 27) by ARTHUR B.W. (Editor), DURLAUF, S. (Editor), LANE, D.A. (Editor)

20. MCMASTER, M.: 'The Intelligence Advantage : Organizing for Complexity' (Butterworth-Heinemann, 1996)

21. GELL-MANN, M.: 'The Quark and the Jaguar: Adventures in the Simple and the Complex' (WH Freeman, 1994)

22. GELL-MANN, M. *Complexity J.* Vol. 1, No.5, 1995/96

23. GOODWIN, B.: LSE Strategy & Complexity Seminar, on 23/4/97, report on http://www.lse.ac.uk/lse/complex

24. **CHECKLAND,** P.: 'Systems Thinking, Systems Practice' (John Wiley, 1981)

25. CHECKLAND, P. & **SCHOLES,** J. 'Soft Systems Methodology in Action' (John Wiley, 1990)

26. **VARELA,** F.: paper given at the 'Complexity & Strategy Conference' London May 1995

27. VARELA, F. & **MATURANA,** H. 'The Tree of Knowledge' (Shambhala, 1992)

28. **ASHBY,** W.R.: 'Self-regulation and Requisite Variety' in Systems Thinking, 1956, Ed by F E Emery, (Penguin 1969)

29. KAUFFMAN, S. & **MACREADY**, W.: 'Technological Evolution and Adaptive Organizations', *Complexity J.* 1995, Vol 1 No 2 pp.26-43

30. KAUFFMAN, S.: Complexity and Technology Conference, London, 11 March 1997

31. MATURANA, H.: Workshop at the Open University, March 1997

32. OLIVER, D. & **ROOS**, J.: 'The Poised Organisation: Navigating Effectively on Knowledge Landscapes' a Paper presented at the Strategy & Complexity Seminar, London School of Economics, 13th February 1997 and on http://www.imd.ch/fac/roos/paper_po.html

ALSO:

32. AXELROD, R.: 'The Evolution of Cooperation' (Penguin, 1990)

33. BOVAIRD, T. & **SHARIFI,** S.: 'Partnerships and Networks as Self-Organising Systems: A Case Study of Rural Acion for the Environment' Research Paper, Sept 1995

34. ESPEJO, R. & **HARNDEN** R.: 'The Viable Systems Model: Interpretations and Applications of Stafford Beer's VSM' (Wiley, 1992)

35. GLEICK, J.: 'Chaos'" (Heinemann Ltd, 1987) reprinted 1990

36. LEWIN, R.: 'Complexity: Life at the Edge of Chaos' (Macmillan, 1993)

37. LUHMAN, N.: 'Essays on Self Reference' (Columbia, 1990)

38. PEAK, D. & **FRAME,** M.: 'Chaos Under Control: The Art and Science of Complexity' (WH Freeman, 1994)

39. SEGEL, L.: 'Grappling with Complexity' *Complexity J.* , 1995, Vol 1, No2

40. WALDROP, M.M.: 'Complexity: The Emerging Science at the Edge of Order and Chaos' (Penguin, 1992)