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## Refereed paper

# Complex adaptive systems (CAS): an overview of key elements, characteristics and application to management theory

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## ABSTRACT

**Objective** To identify key elements and characteristics of complex adaptive systems (CAS) relevant to implementing clinical governance, drawing on lessons from quality improvement programmes and the use of informatics in primary care.

**Method** The research strategy includes a literature review to develop theoretical models of clinical governance of quality improvement in primary care organisations (PCOs) and a survey of PCOs.

**Results** Complex adaptive system theories are a valuable tool to help make sense of natural phenomena, which include human responses to problem solving within the sampled PCOs. The research commenced with a survey; 76% (n16) of respondents preferred to support the implementation of clinical governance initiatives guided by outputs from general practice electronic health records. There was considerable variation in the way in which consultation data was captured, recorded and organised. Incentivised information sharing led to consensus on coding policies and models of data recording ahead of national con-

tractual requirements. Informatics was acknowledged as a mechanism to link electronic health record outputs, quality improvement and resources. Investment in informatics was identified as a development priority in order to embed clinical governance principles in practice.

**Conclusions** Complex adaptive system theory usefully describes evolutionary change processes, providing insight into how the origins of quality assurance were predicated on rational reductionism and linearity. New forms of governance do not neutralise previous models, but add further dimensions to them. Clinical governance models have moved from deterministic and 'objective' factors to incorporate cultural aspects with feedback about quality enabled by informatics. The socio-technical lessons highlighted should inform healthcare management.

**Keywords:** clinical governance, complex adaptive systems, informatics, primary care, quality assurance, socio-technical

## Introduction

There are various governance models that guide current quality improvement programmes used by health services.<sup>1,2</sup> This paper summarises a review of complex adaptive system explanations of problems in networked organisations. It draws on examples from primary care informatics, which include workarounds and use of financial incentives to overcome obstacles.

Complex adaptive systems (CAS) is a framework that assists thinking about the nature of quality improvement programmes in primary care organisations (PCOs). The review includes practical frameworks, designed to ensure delivery of health service quality improvements enabled by developments in primary care informatics. The findings should improve our

understanding of management approaches and the control of new organisational forms.

## Method

We carried out a literature review and developed a theoretical framework that facilitates interpretation of the case studies upon which this series of papers is based.<sup>2</sup> Approaches that suit CAS are identified and examined. Complexity thinking introduces new and different metaphors and provides a language for understanding the nature of responses to quality improvement programmes in PCOs. The review discusses concepts dealing with relations, interdependencies, governance and managerial responses to quality improvement programmes in PCOs.

## Results

### Complex adaptive systems

Complex adaptive system ideas are associated with developments in second-order thinking. The second-order view of systems describes recursive interactions

between layers of systems (control loops and feedback); principles that guide a variety of systems to achieve their purpose by 'the return of information to form a closed loop'.<sup>3</sup>

The ideas of feedback, non-linear causation and self-regulation mark the move towards a collaborative, network-based understanding of governance.

In 1984, the Santa Fe Institute in New Mexico studied the behaviour of CAS. A state between stable and unstable behaviour was discovered, attributable to interactions between agents and elements within a system. Activity was simulated using simple rules applied by each of a network of moving digital agents (boids).<sup>4-6</sup> The idea of 'simple rules' has subsequently been applied by organisational theorists as a way of interpreting the complex behaviour found in organisational communities.<sup>7-13</sup>

Key elements, features and management principles that characterise CAS are summarised in Table 1.

Complex interactions and interdependencies emerge within CAS which cannot be understood or predicted simply by studying individual elements of the system; novel system behaviour emerges. Humans possess the capacity to reflect, which may result in alternative paths of action to those prescribed within simple rules. The interacting component units within CAS result in a system-wide governance, because influence is exercised both by the system on the units and by the units

**Table 1** CAS elements and management principles

Core CAS elements	Features	Management principles
Multiple agents with schemata	Informal, collaborative networks of individuals that partner and contribute to solution making Connectivity and interdependence between agents Degrees of connectivity	Respect democratic principles that lead to mutual adjustment; jointly steer courses of action
Self-organising networks	Holistic patterns formed through human interactions Causation Feedback	Adjust the fitness landscape: offer incentives, and longer term rewards by setting priorities. Apply simple design principles because they turn into rules; ensure that lines of communication flow across network, so authority and legitimacy become vested in the process as a whole, not on the perspective of one
Coevolution	Innovative pathways of governance emerge – a variety of what is known as 'emergent behaviour' in CAS	Appreciate and monitor the implications of feedback, non-linear and mutual causation
System adaptation	Networks represent additions to hierarchies	Respect individuals and their organisations that exist in an ecosystem – avoid major change

on the system – termed ‘mutual causation’. Quality assurance is introduced next, a formal framework within which quality health care is currently delivered within PCOs.

## Quality assurance

Quality assurance is associated with the application of scientific methods to management and 20th century industrial production. Its aim is to increase the proportion of products without faults. Quality improvement in health care is sometimes bedevilled by the difficulty of defining universal measures of a ‘best’ (or sometimes even ‘good’) outcome for patients, bearing in mind the very variable case mix receiving health care and the considerable uncertainty about cause and effect in some individual (and occasionally general) cases. This makes it particularly suited to a CAS approach, and both outcome-oriented and process-oriented measures need to be considered to effectively evaluate performance from a user/service satisfaction perspective. There is a consensus that the key characteristics of a healthcare quality assurance framework<sup>14</sup> include:

- **Leadership** Senior management should actively participate in quality assurance programmes, as partners rather than pharaohs.
- **Organisational characteristics** The organisation should provide moral and material support.
- **Characteristics of the health professionals** They should be willing to take part in the programme and be responsive to findings.
- **Technical quality of monitoring system** Efficient data collection processes are necessary in order to minimise the costs of quality measurement.<sup>15</sup>

Performance is measured before the use of change strategies and is repeated at intervals, termed the quality improvement cycle. The quality improvement cycle requires monitoring systems to review aspects of performance on a continuing basis. It presents in various forms that include ‘plan–do–study–act’<sup>15</sup> and ‘plan–do–check–act’<sup>16</sup> cycles. Developments in informatics and improved availability of performance data has led to transparency of outputs and public disclosure of the performance of healthcare providers.<sup>17,18</sup> The following section reviews the formulation of the quality improvement cycle proposed as part of the European Foundation of Quality Management (EFQM)<sup>a</sup> Excellence Model.

## European Foundation of Quality Management Excellence Model

The government explicitly commended the EFQM Excellence Model as a management framework for clinical governance,<sup>19–22</sup> as a model that provides:

an enhanced focus on aspects of excellence that are becoming increasingly important such as the management of partnerships and knowledge ... explicit focus on the value to users of the ‘plan, do, check, act’ cycle; a need to relate everything that is done, and the measurements taken, to what policy and strategy is seeking to achieve. (www.efqm.org)

The EFQM Excellence Model reflects a logic known as RADAR which consists of the elements: results, approach, deployment, assessment and review. Advocates of the EFQM Excellence Model suggest it has an inherent capacity to reflect the processes of quality service provision. The EFQM Excellence Model posits that five sub-criteria need to be addressed:

- 1 processes are systematically designed and managed
- 2 processes are improved as needed, using innovation in order to fully satisfy, and generate increasing value, for customers and other stakeholders
- 3 products and services are designed and developed based on customer needs and expectations
- 4 products and services are produced, delivered and serviced
- 5 customer relationships are managed and enhanced.

The model is based on nine criteria. Five of these are ‘enablers’ and four are ‘results’. The ‘enabler’ criteria cover what an organisation does. The ‘results’ criteria cover what an organisation achieves. ‘Results’ are caused by ‘enablers’ and feedback from ‘results’ helps to improve ‘enablers’. The EFQM Excellence Model is a non-prescriptive framework that recognises there are many approaches to achieving sustainable excellence in all aspects of performance. The model is based on the premise that excellent results with respect to performance, customers, people and society are achieved through partnerships, resources and processes. In essence, the model subscribes to Deming’s philosophy of continuous plan–do–study–act, and to his notion of production as a cooperative task undertaken by a network of semi-autonomous individuals who subscribe to the common goal of producing high-quality outputs.<sup>23</sup> Processes are driven by self-assessment, achieving objectives and controlling risks. The EFQM describe self-assessment as a comprehensive, systematic and regular review of an organisation’s activities and results, these referenced against an objective standard of business excellence. NHS organisations use outputs from self-assessment as part of their business planning processes, applying the model as a basis for operational and project review.

<sup>a</sup> EFQM is the trademark of The European Foundation of Quality Management, Brussels, Belgium

## Primary care informatics

The publication of high-profile cases of unacceptable levels of performance, typified by the reports of the Shipman Inquiry,<sup>24</sup> perturbed GPs' professionalism. Case study findings, including those from a small-scale survey, with questionnaires circulated across a PCO sample (42% response rate – 57% GPs, 33% primary healthcare team nurse members, 10% managers), suggest that the need to develop information systems and provide evidence of conformance with acceptable standards was seen as irrefutable. Overall, the results provide valuable insight into the development of key themes (see Figure 1). An emphasis on a positive approach, and the sharing of information, were widely considered a vital part of the change process:

- self-assessment and sharing of associated outputs through feedback was perceived as a valuable method to local governance of quality improvement
- measures of quality/effectiveness of practice became increasingly transparent, visible and incentivised. For example, there was clear linkage to key organisational performance indicators, e.g. the National Service Framework (NSF) for Coronary Heart Disease.

The findings provide useful insight into the attitudes, perceptions and opinions of those involved in implementing clinical governance within the PCO sample:

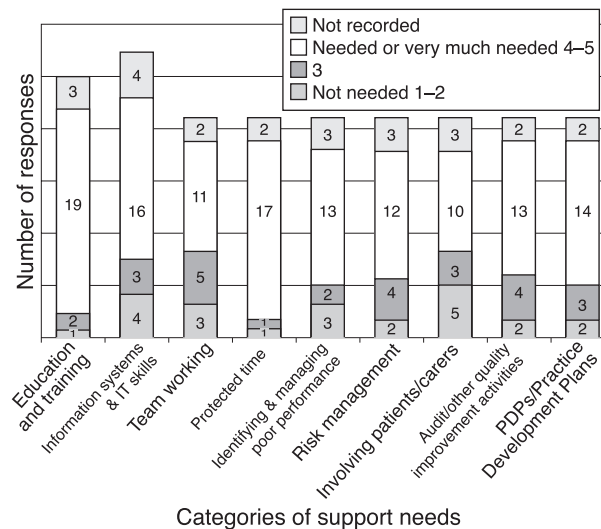
'We'll have a phase of them getting their data straight, for 12 months or so, but in the future we can be pretty confident that the information we have is an accurate reflection of quality.' (PCO Clinical Governance Manager)

Benchmarked results (in terms of quality assurance mechanisms) encourage a levelling of performance by reducing variation of practice supported via peer review. Cowley *et al* (2003) report that: 'The advent of the NSF for Coronary Heart Disease (CHD) in 1999, a comprehensive public health programme, with its milestones and targets, acted in some part as a balancing process, made practices stop and think "How can we do this as well as everything else?".'<sup>19</sup> To enable this to be delivered in the complex environment of primary care, the Health Informatics Programme for CHD (HIP for CHD), funded by the Department of Health (DoH), began in 2000 and ran until 2003. It developed practical tools and quality methods that clinicians used both interactively in the consultation and for continuous learning, together with methodologies that enabled general practices to become 'learning organisations'.

## Discussion

This study shows how emergent behaviours can coalesce and form informal structures, which may then be readily formalised. Key activities developed in response to the introduction of clinical governance include:

- standardised coding
- improved data collection techniques
- development of indicators for the purpose of comparison and feedback
- monitoring



**Figure 1** Support needs of practices (based on GP, primary healthcare nurse, care team and manager responses)

- self-evaluation
- benchmarking
- peer review
- making specific arrangements for achieving changes in performance.

Analysis shows that structure emerges as a patterning of behavioural themes. Where contractual changes resonate with emergent patterns, the changes are more likely to be accepted.

## Conclusion

The local responses described in this paper were subsequently formalised within a revised UK contract for primary care in 2004, which provided an opportunity for drawing together the various and disparate quality improvement strands: 'These included organisation policy context; care and treatment; new ways of working and the increased use of technology in support of these processes'.<sup>19</sup>

Drivers included incentive payments for target achievement. Key messages included feedback from, and computerisation of, previously disconnected processes, and the need for cooperation amongst semi-autonomous agents – clinicians, managers, administrators and informaticians – to sustain and improve the quality of outputs.

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## CONFLICTS OF INTEREST

None.

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