NETWORKS IN A DIGITAL WORLD

A CYBERNETICS PERSPECTIVE

Complete Research

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Abstract

Researchers and practitioners in Information Systems (IS) share an interest in the application of information technologies (IT) to organisational systems. Such technologies today are overwhelmingly digital, with the context of their use being human activity organised into increasingly networked forms. This paper makes sense of these connections via theories of cybernetics, particularly Beer's Viable System Model. It aims to bring together a disparate body of theory – on networks – to produce a more synthesising, 'meta' account, thus helping to explain both the importance of digital technology to network growth, as well as the basis on which network structures can be stable, flexible and effective. It discusses the emergence of network structures across society, noting various forms of networks and the contested nature of the concept. It goes on to discuss the development of digital artefacts and infrastructures. The importance of network stability and flexibility is then analysed, leading to an account of system properties using management cybernetics. It is argued that the notions of self-organisation and self-regulation – key characteristics in viable systems – can be used to understand why network structures have emerged and thrived since the 1990s. It concludes by noting the importance of these ideas for future IS research.

Keywords: Inter-organisational networks, digital technology, cybernetics, self-regulation.

1 Introduction

Researchers and practitioners in Information Systems (IS) share a common interest in the application of information technologies (IT) to organisational systems (for example, Avison and Fitzgerald, 2006). Such technologies nowadays are overwhelmingly *digital* in nature; and the context of their use – organised human activity – is increasingly taking place in *networks* of one kind or another (for example, Benkler, 2006). This paper seeks to make sense of these links by use of theories of cybernetics, particularly Beer's Viable System Model (for example, 1985). Its purpose in doing this is to connect a reasonably disparate body of organisation theory, on networks, to a more synthesising, 'meta' account, and thus help to explain both the importance of digital technology to network growth, but also the basis on which network structures can be stable, flexible and effective – that is, they can endure over time, grow and innovate, and thereby continue to add value to their members and customers.

The paper starts by discussing the emergence of network structures across society, noting that networks exist in various forms and that the term itself is hardly an uncontested one. It moves on to discuss the development of digital artefacts and infrastructures, observing that these themselves can be seen as both the enablers and outcomes of more horizontal organisational arrangements. The importance of network stability and flexibility is then discussed, leading to an account of system properties using ideas of management cybernetics. It is argued here that the notions of self-organisation and self-regulation – key characteristics of autonomous, viable systems – can be used to understand why network structures have emerged and thrived in both social and market systems, particularly since the 1990s. The paper concludes by noting the importance of these ideas for future IS research.

2 The rise of heterogeneous networks

Over the past two decades, momentum has gathered towards more networked forms of social and economic organisation. For Castells (2004; 2010), this 'network society' is the result of various social, technological, economic and cultural transformations all coming together to produce a new (global) social structure. While networks *per se* are nothing new, says Castells, *digital networking* technologies have allowed social and organisational networks to expand and reconfigure way beyond the complexity of traditional network forms (Castells, 2010, p. xviii). He is supported here by Benkler (2006), who likewise argues that the change brought about by the 'networked information environment' is deep and pervasive, leading to structural change in the nature of economic and social organisation (Benkler, 2006, pp. 1-2).

For both authors, the rise of digital technologies, most notably the Internet, has led to new communications patterns between individuals. Among other things this has resulted in more 'horizontal' flows, as digitally-savvy citizens have taken advantage of the increased freedom to share and exchange information, knowledge and culture. In economic terms, too, a new 'organisational logic' is also emerging, says Castells (2010). While related to current technological developments, he contends however that this is not dependent upon such change. Post-Fordist-type reorganising strategies, Castells points out, first emerged in the 70s and 80s – predating the arrival of the new networking technologies (pp. 164-5). Nonetheless, the new digital communications platforms provide novel capabilities for supporting these strategies and furthering the organising logic (see also Tapscott et al., 2000; Sambamurthy et al., 2003).

2.1 From hierarchies to networked enterprises

At the root of organisational change here is the shift from 'mass' (standardised) production towards more 'flexible' (customised) production systems (Harvey, 1990; Castells, 2010, pp. 166). Among the trends involved, three mentioned by Castells are worth noting. The first is the swing away from large, vertically integrated structures, where production took place within a single corporate hierarchy. Such organisation was often accompanied by a high division of labour, and repetitive, deskilled work with little worker autonomy (Piore and Sabel, 1984). Secondly, and a corollary of this, has been the rise of small, specialised businesses, sometimes clustered around larger (client) corporations, or otherwise operating as part of an (inter)organisational network of production. Thirdly, there is the rise of new methods of management, such as 'just in time' systems of supply, autonomous (self-organising) work groups and decentralised decision-making (Castells, 2010).

The importance of IT to the new organising logic leads Castells to introduce the notion of 'the network enterprise', defined as *"that specific form of enterprise whose systems of means is constituted by the intersection of segments of autonomous systems of goals."* (Castells, 2010, p. 187, original emphasis). The components of the network, he goes on to say, are both autonomous and dependent vis-a-vis the network. As such they "may be part of other networks, and therefore of other systems of means aimed at other goals" (Ibid.). This embedding of systems in a range of other systems is a point we will develop below.

For Castells, then, the network enterprise *is* the organisational form of the informational, global economy. Here, successful firms are those able to generate knowledge and process information efficiently, and be flexible to change their 'means' as goals change due to cultural, technological and institutional disruptions (2010, p. 188). Such network forms would be unthinkable, he notes, without the increased power of IT, in particular the digitisation of telecommunications, increased broadband speeds, and improvements in the performance of devices and software connected to such communications networks (p. 186). In making this argument, Castells cites Bar and Borrus's 1993 paper, *The Future of Networking*, whose arguments indeed seems prescient, not least because of the similar points advanced in Brynjolfsson and McAffee's (2014) work, 'The Second Machine Age', more than 20 years later.

2.2 Conceptualising networks in the second machine age

For Brynjolfsson and McAffee, too, the exponential growth of computer storage capacity and processing power, backed up by similar leaps in download speed, marks the *first* of the three characteristics of a new age. The *second* characteristic is the digitisation of information and media, including text, sound, video, sensors, and so on (p. 60). For Brynjolfsson and McAffee, these advances lay the foundation for the *third* characteristic of the second machine age, 'combinatorial innovation'. This occurs where previous innovations (in new digital technologies, the data they support and the standards that allow them to interoperate) act as 'building blocks' for subsequent innovations, allowing for ideas and resources to be combined and recombined in new and inventive way, making them more valuable in the process (Brynjolfsson and McAffee, 2014, pp.78-79; Yoo et al., 2012, pp. 1402-03).

In as much as business and enterprise networks have flourished with the growth of networked technologies, they have much in common with the explosion of 'nonmarket' production, as described by Benkler (2006). Whether paid or otherwise, Benkler highlights in particular the growth of 'peer production' systems, driven by social instincts for sharing and collaboration (Benkler, 2006, pp. 91-127). Both business and social networks also reflect a move from hierarchical control towards autonomy, as well the use of information technologies and digitised content. In both cases, too, the networks in question may be of a temporary nature, existing for as long as it takes to complete a project or produce an information-based artefact – a so-called 'virtual team' or 'virtual organisation' (Morgan, 1997, p. 52; Jackson, 1999). Morgan here draw's on Bennis's (1966) notion of an 'adhocracy' – a structure that is organic and time-limited and highly suited to complex, uncertain environments. This is a significant point because it reminds us that all structures are embedded within a range of business, social and economic contexts, in which they need to fit over time.

The issues of 'scope' and 'duration' in conceptualisations of (inter)organisational relations, as apparent in notions of adhocracy and virtuality, are also worthy of reflection here. One-off market relations – where goods or services are bought on the basis of a spot contract – contrast with more open-ended situations, where a 'relational' contract may endure over time. Similarly, depending on whether the content of the relationship is a self-contained project – rather than a collaboration stretching across several functional areas – the nature of the relations will vary again (see Perri 6 et al., 2006, pp. 6-7). These examples show how organisations are continually drawn into relations with other entities, which affect the nature of the arrangements, and the extent to which they are 'collaborative' or merely 'market' based. Indeed, the extent that 'network' relations can be distinguished from 'market' or 'hierarchical' relations is often a matter of degree rather than kind. As the authors note:

> "At the very least ... there are 'hierarchical networks' and 'market-like networks' rather than networks being distinct from either hierarchies or markets as forms of organisation. As a consequence, networks do not form a single distinct category of inter-organisational relations, with features shared by all and only those forms properly classified as 'networks' and which can be marked off clearly from 'markets' or 'hierarchies'." (Perri 6 et al., 2006, pp. 3-4)

This argument, the authors go on to say, suggests that the nature of the accountabilities in both inter-organisational and single (hierarchical) organisation systems may not be fundamentally different in character (p. 4). Like the authors, the current paper will use this point as the basis on which to advance subsequent analysis. In our own case, this is to argue for an over-arching theory of organisation in cybernetics terms, which is generalisable across all organisations but can particularly help to explain the success or otherwise of network structures (for example, Beer, 1979; 1981 and 1985).

We can see from the above discussions that there is a range of phenomena associated with the idea of a 'network society'. It involves market-based enterprises, as well as voluntary, nonmarket communities. While (networked) information technologies may well play a key role, the move towards more 'horizontal' organisational structures began well before the 'full force' (Brynjolfsson and McAfee's 2014 term) of recent technological developments. Despite this, there is general agreement that networked, digital IT has accelerated the trend towards more networked ways of organising.

Like Castells, Morgan, for example, sees the growth of 'networked intelligence' as part and parcel of emerging (Post-Fordist) business forms. But citing the example of IT systems in supermarket stock control , he also notes how, "The system of organisation embedded in the design of such information systems replaces more traditional modes of human interaction ... It also links organisations that used to have distinct identities – manufacturers, suppliers, banking and finance companies – into an integrated information web (p.81)". Similarly for Tapscott, et al. (2000), the sort of network structures that began to arise since the 1990s would be inconceivable without developments in the technology and the 'digital capital' they allow to be created, shared and traded. To arrive at a deeper understanding of how these technologies are shaping this new world, then, we will now seek a richer conceptualisation of the 'digital' phenomena in the network society.

3 Digitisation and the network society

If we are increasingly living in a network society, then there is a welter of opinion that it is also one that is 'digital'. A number of works from the mid-1990s on have presaged the arrival of an era of 'bits' (binary digits), where aspects of the world (numbers, text, images, videos, etc) are captured, processed, stored and communicated in digital, rather than analogue, form (for example, Negroponte's (1996) *Being Digital*; Tapscott's (1998) *Growing up Digital* and Evans and Wurster's (2000) *Blown to Bits)*. Digital technologies here are seen routinely to penetrate into the core of everyday products and services, with organisational systems too increasingly built of management systems composed on intelligent machines with digital sensors, networks and processors (Yoo, et al., 2012, p.1398).

Digitisation, as we've already seen, has been cited as a cornerstone of the so-called 'Second Machine Age'(Brynjolfsson and McAffee, 2014). But it is only in recent times – towards the end of the first decade of the twenty-first century – that digital technologies have garnered the 'full force' needed to emulate 18th century innovations in industrial power (engendered by Jamese Watt's steam engine), and thus have the scope to change whole systems of production, consumption and industrial organisation (Brynjolfsson and McAffee, 2014, p. 8). As related above, this reflects the remorseless working of 'Moores Law' (in terms of transistor density), and increases in processor and broadband speed (Brynjolfsson and McAffee, 2014, p. 40).

A deeper appreciation of digital artefacts is therefore warranted if we wish to understand the connections between technological change and developments in organisational and social structures. Not least, this also addresses the much-observed *absence of the IT artefact* from IS research and writing (for example, Orlikowski and Iacono, 2006). But it is also important, as we will see, given the way digitising *itself* is bound up with the processes of networking and vertical disintegration (for example, Tilson, et al., 2010).

3.1 The digitisation of products and artefacts

To begin, we need to recognise that processes of digitisation involve more profound change than simply encoding analogue information in a digital format (Yoo, et al., 2010). As Yoo himself points out

(2010, pp. 225-6), we can now easily embed software capabilities into non-digital artifacts, making them ‘programmable’ (able to perform multiple functions), ‘addressable’ (where they can be identified within a computing architecture), ‘senseable’ (that they themselves can collect data), ‘communicable’ (they can then report on this data), and ‘memorisable’ (they can remember things). Use of the above features, Yoo notes, also makes such artifacts ‘traceable’ in time and space, as well as enabling them, and their data outputs, to be ‘associable’ – related to other actors, artefacts and places – we might even say ‘networked’ (Ibid.).

According to Yoo et al. (2010), the production and use of digitised products thus engenders a new set of ‘organising logics’ – arrangements that enterprises need to adopt to cope with the demands presented by the new technology given the firm’s environmental and strategic imperatives (Sambamurthy and Zmud, 2000, p.107). We can better understand the issues here by recognising what Yoo et al. refer to as the ‘layered modular architecture’ – a hybrid of the ‘modular’ architecture of physical products and the ‘layered’ architecture of digital ones. Here, the layered architecture of digital technology is embedded into physical products, enhancing functionality with software capabilities (2010, p. 725).

There are four layers in this digital architecture. First are the *devices* themselves, which include the ‘physical machinery’ (hand-held and computer hardware) and ‘logical capability’ (the operating system). Second is the *network* layer, which itself includes ‘physical transport’ (cables and radio spectrum, for example) and ‘logical transmission’ (such as network protocols). Third is the *service* layer, which provides the application functionality that allows users to create, access and manipulate content. Fourth is the *contents* layer – texts, images, videos, etc, together with meta data such as content tags, copyrights and geo-tags – that users engage with via service applications (Yoo et al., 2010, pp. 726-7).

This conceptualisation highlights a number of issues worthy of note. For a start, say the authors, there is ‘no fixed product boundary’ to such digital artefacts, meaning that the components in the architecture are ‘product agnostic’ (p. 728). The creator of one layer (say content) cannot know what software will be employed to manipulate that content, nor what device will be used. And as the content takes a ‘homogenised format’, it can be combined – or ‘mashed’– to produce new combinations of output. Such digital products therefore typify what Zittrain refers to as ‘generativity’, “*a system’s capacity to produce unanticipated change through unfiltered contributions from broad and varied audiences*” (2008, p. 70, original emphasis). Finally, such digitised products can also become ‘platforms’ for others to build components and services – as seen, for example, with the app developers exploiting the arrival of smart-phones.

It is these issues and characteristics of digital technology that have brought an accompanying shift in the organising logic of the firm. For traditional physical products – those with an ‘integral’ architecture, where interfaces between components are not standardised and are tightly coupled – the dominant logic is the *vertically integrated hierarchy*. “Here, a single firm carries out the majority of innovation required for competitive survival” (Ibid, p. 727), the key sources of value creation being scale and scope (see also Henfidsson et al., 2014). In contrast, a modular architecture leads to *vertical disintegration* of a firm’s design and production functions, with IT used to help address the communication and coordination requirements of the (new) business models and inter-firm relationships that result (Sambamurthy and Zmud, 2000, p. 106). Where digital products are concerned, however, given the generative nature of the architecture achieved through the loose couplings of layers, more heterogeneous (external) actors are brought into design and production (Yoo, et al., 2010, p. 730).

Citing Henfridsson and Lindgren (2010), Yoo et al. provide fresh insight here into the *digital* nature of Post-Fordist production. As they put it:

> “...as most subsystems of an automobile are becoming digitised and connected through vehicle-based software architectures, an automobile has become a computing platform on which

other firms outside the automotive industry can develop and integrate new devices, networks, services and content." (Yoo et al., 2010, p. 729)

More than just providing the 'means' for the articulation of lean, horizontal, Post-Fordist enterprises, digitisation at the *product* level is thus a secondary driver in favour of networked (inter)organisational relations. Further force is added once we expand our analysis to consider the *infrastructures* that digital convergence has also engendered.

3.2 Digital infrastructures and organisational relations

According to Tilson et al. (2010), digital infrastructures can be defined as "the basic information technologies and organisational structures, along with the related services and facilities necessary for an enterprise or industry to function" (p. 748). Such infrastructures are also, they continue, "shared, unbounded, heterogeneous, open, and evolving sociotechnical systems comprising an installed base of diverse information technology capabilities and their user, operations, and design communities (pp. 748-9).

In expounding (and bemoaning) the oft-neglected importance of infrastructures to IS research, Tilson et al. make an important distinction between the notion of 'digitising' and 'digitalisation'. The former, they suggest, is the *technical process* of converting analogue content into bits. Digitalisation, on the other hand, is seen as the "*sociotechnical process* of applying digitising techniques to broader social and institutional contexts that render digital technologies infrastructural (p. 749). Thus, as corporate information infrastructures become fully digitalised, new generative dynamics emerge, enabling new forms of communication and collaboration across organisational boundaries (p.751). Moreover, say Tilson et al., digital infrastructures are also 'recursive' (they can be recombined to generate new infrastructure), they are extremely 'scaleable' (their components can easily be upgraded or replaced – often with cheaper and more powerful elements), and they are inherently 'flexible,' thanks to the scope and reach brought about by digital convergence more generally (p. 752).

Both these processes – digitisation and digitalisation – thus give force to the erosion of organisational and industrial boundaries, leading to new eco-systems of heterogeneous actors, often working in internetworked enterprises, producing goods and services for what are sometimes entirely new industries (for example, mobile phones and smart-phone apps). As we have seen, such developments are not simply 'digitally-*enabled*', even if – as Castells points out – many of the economic and industrial trends predate the 1990s innovations in technology. The implication of digital components in many of today's products and production processes, together with the importance of open and expansive digitalised infrastructures, means that digital technology is deeply embedded in the networks of social and economic relations characteristic of the new world (be it a 'network' or 'digital' society, depending on your vantage point.).

3.3 Stability and change in a digital world

For Tilson et al. (2010) at least, the generativity involved here also involves a paradox, encompassed by the opposing logics of 'stability' and 'flexibility' that operate across infrastructure layers and components. Digital infrastructures, they note, need to be stable enough to allow the enrolment of new artefacts, processes and actors, while also having the flexibility to allow unbounded growth (p. 753-4). The critical issue, it is suggested, involves the notion of a 'control point' – how we define and control a set of connections in a sociotechnical system that help determine behaviours and constraints for other elements in the system (pp. 754-5).

This is a crucial insight, but we can argue that the tension between stability and flexibility extends beyond the analysis of infrastructures and into the very networks of which they may be part. In each case, the issues of 'order' and 'change' are important. Given the enabling power and generativity of digital technology to support extended horizontal relations between actors (be they individuals or organisations), it should be no surprise that networks can be quickly built and maintained, nor that they provide options and capabilities attractive to firms seeking competitive advantage (for example, Sambamurthy et al., 2003). The question we then need to ask ourselves is why some of these forms achieve an apparent 'spontaneous order' and endure over time. This is rarely asked in the literature on networks, and even less in that on digital technology. To arrive at an answer we will now turn to ideas from the world of cybernetics and systems thinking.

4 Network formation and growth

How are networks formed? How do they grow – and sustain a particular order? And what role do digital technologies play in this process? To being with, let us address the first two of these questions.

4.1 The creation of social networks

In recent times 'social network theory' has played an important role in understanding the way individuals and organisations form cooperative relations (Kenis and Oerlemans, 2008). Since Granovetter's (1973) groundbreaking work on the 'strength of weak ties', a range of other theorists have sought to understand the actions, strategies and systems of connection between different actors in social and organisational situations (e.g. Berkowitz, 1982; Axelrod, 1984). In social network theory, the actors – individuals, teams and organisations – are seen as the 'vertices' (or 'nodes') that form relations (also called 'edges' or 'ties') with other actors (Kenis and Oerlemans, 2008, p. 291). Links can be formal or based on friendship, and will vary in *strength* – in Granovetter's original paper this is reflected by a combination of time, emotional intensity, intimacy and reciprocity (1973, p. 1361).

Kenis and Oerlemans' account here reminds us of the positioning of networks amid other inter-organisational relations. As they put it: "In contrast to arm's-length market relationships, which can also be considered ties, the relationships in a network approach are relatively stable, although less so than in a hierarchy (2008, p. 291). In this sense, they are not 'one-off', as they might be in a 'spot contact' (for example, see Perri 6 et al., 2006), nor are they organised into enduring hierarchical structures. While this is true for inter-organisational relations, it is also the case with networks more generally, some of which have a tendency to exhibit rapid growth.

4.2 Complex networks (social, organisational or otherwise)

In studying expansive network phenomena such as the Internet, and the (social) communities that are adding to and using it, we need to understand more about how networks can form and grow – often exponentially – while also maintaining a recognisable structure over time. As the Second Law of Thermodynamics reminds us, entropy in any system will increase over time, so stability cannot be assumed as a natural state of affairs.

The creation of 'order out of chaos' is one that has puzzled thinkers from across the scientific spectrum. Castells (2010), for instance, notes attempts to create a new (interdisciplinary) paradigm to understand how complex structures can emerge from seeming random processes. He himself points to the efforts of mathematicians to model the dynamics of networking and thus grapple with the non-linear logic of network formation and growth (pp. 74.5). Of particular relevance here (though not mentioned by Castells) is the work by Barabasi and Albert (1999) to understand phenomena as diverse as genetic networks or the World-Wide-Web. Large scale networks such as these, say Barabasi and Albert, exhibit a complex topology, given their patterns of connectedness and barely discernible boundaries. In such networks (like Kenis and Oerlemans, 2008), the 'vertices' are represented by the elements of the system – such as an individual or organisation, or even proteins or genes – with the 'edges' represented by the interactions between them – social in the former cases, chemical in the latter ones (Barabasi and Albert, 1999, pp.509-10).

With improvements in computerisation and data acquisition, say Barabasi and Albert, it has become possible to understand the dynamical and topological stability of large networks. Independent of the systems studied, this has shown that large networks 'self-organise' into a 'scale-free' state – a feature not predicted by previous random network models, they point out (p. 510). Such networks are 'scale-free' in the sense that (some of) their vertices may not simply be related to others in a purely randomised way but exhibit very *high levels of connectivity* to other vertices – and thus other networks. This finding runs counter to previous models, say the authors, because of a failure to incorporate 'growth' and 'preferential attachment' in their understanding of networks. More specifically: (1) networks expand continuously by the addition of new vertices and (2) the new vertices attach preferentially to sites that are already well connected (Barabasi and Albert, 1999, pp. 509-10.). (Readers of Malcolm Gladwell (2000) may see a parallel here with his notion of 'connectors'.)

The element of 'self-organisation' in large networks is also mentioned in Castells' discussions of system chaos and complexity. Noting the work of Gleick (1987), Castells points out that thinkers in this area:

> "...focus on understanding the emergence of self-organising structures that create complexity out of simplicity and superior order out of chaos, through several orders of interactivity between basic elements at the origin of the process." (2010, p. 74)

Put another way, complexity (and order) is gradually built up as simple systems become linked to others and networks form and grow. In addressing such matters, Castells goes on to applaud endeavours here that seek to find "common ground for the intellectual cross-fertilisation of science and technology in the Information Age" but suggests that the approach (just quoted), "seems to forbid any integrating, systemic framework" (Ibid.). Quite why is not clear, although he does go on to posit that the epistemological value of such work could come from 'acknowledging the self-organising character of nature and society'. Indeed; and by turning to an extant body of knowledge – cybernetics and systems thinking – that has much to offer here in terms of an epistemology coupled to a theory of self-organising systems, we will now do exactly that.

5 Cybernetic systems and self-organisation

5.1 Order out of chaos

In his Irvine Memorial Lecture at the Unviersity of St Andrews (5 March, 1975) British cyberneticist Stafford Beer cited the *Book of Proverbs* (Kings James Bible, 30: 27): "The locusts have no king, and yet they go about in bands." They do not have hierarchies of command, he pointed out; they are in a state of 'anarchy', the Greek 'anarchos' literally meaning *without a leader*. The key point for Beer is that such systems are *self*-regulating and *self*-organising (see Beer, 1975, p. 25). The networks that grow on the Internet, as social communities of software developers and political movements (c.f. Benckler, 2006), are often similarly 'anarchic', yet they grow – often in a 'scale-free' way – maintain order and identity, and withstand perturbations over time.

The ability of such systems to withstand shocks should come as no surprise. In the same lecture, Beer cites the work of American neurophysiologist-cum-cybernetican Warren McCulloch. McCulloch observed how the reticular formation of the brain stem – 'reticular' meaning that it consists of a complex network of interconnections – provides the brain with a 'redundancy of potential command'. Centralised, hierarchical systems by contrast, have a tendency to rob the system of redundancy, making it highly dependent on the 'leader' (or 'governor') through vertically channelled information paths

(Beer, 1975, p. 24). Of course, this very network design, and the avoidance of a ‘single point of value’, underpins the very conception of the Internet.

In terms of self-regulation, both mechanical and social systems have ‘governors’ (or homeostats) of one form or another that help to regulate the behaviour of a system and maintain its integrity within particular limits – such as keeping the human body at around 37C (Beer, 1975, p. 32). For James Watt’s steam engine (mentioned above in terms of the *first ‘machine age’*), the governor was the name given to the system of two steel balls that rotated with the speed of the engine to close the throttle. This thus reduced speed and ensured the engine did not run out of control (Morgan, 1997, pp. 84-5). All systems that wish to remain ‘viable’ (that is, to maintain a separate existence over time) need similar mechanisms.

5.2 The Viable System Model

Mechanisms of self-regulation (or self-governance) – where there is a redundancy of command – are thus the heart of any viable system. Such ideas are central to the discipline of ‘cybernetics’. For Beer, cybernetics can be defined as the ‘science of effective organisation’, based on principles such as self-regulation and self-organisation. His Viable System Model (VSM) is intended to support this by illustrating the invariant and requisite functions an organisation must have to maintain viability (Beer, 1979; 1985). This is important for IS researchers and designers, of course, given the need to have a robust model of ‘organisation’ when trying to understand the relationship between users, information and the (information) technologies employed to support them (for example, see Checkland and Holwell, 1998).

The Viable System Model states that any system can be thought of as having six component subsystems, plus a wider environment with which it must stay in balance. The subsystems are: (1) its operations, (2) coordination, (3) delivery management, (3*) monitoring, (4) development management and (5) policy (Beer, 1979; 1985; Hoverstadt, 2008, pp. 27-37). A system could, of course, be a department, the organisation as a whole, an inter-organisational network or an Internet community. Taken together, these components enable a system (of whatever form) to carry out its operations, monitor and control them and ensure coordination between subsystems. At a more strategic level, they also allow for the monitoring of the system’s environment, the identification of strategies for change (where the system is out of sync with its environment), and the management of innovation - where the system needs to develop new delivery mechanisms to respond to environmental needs (see Figure 1. below).

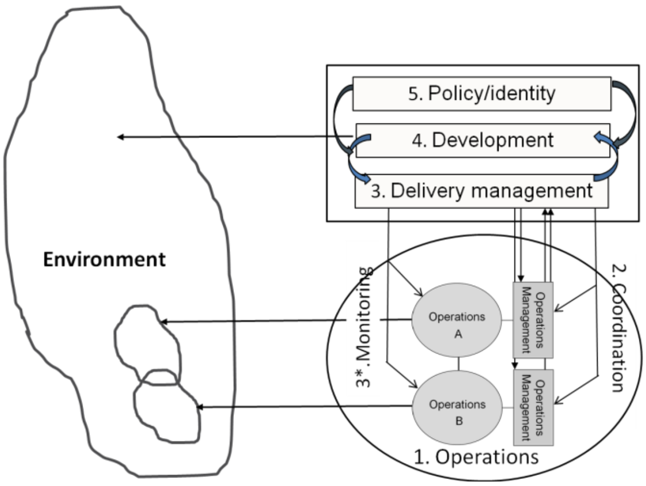

Figure 1. Beer’s Viable System Model

For a system to be viable it must also exhibit 'requisite variety' in relation to the complexity of the environment (Ashby, 1960). For Ashby, complexity could be understood mathematically in terms of the number of possible states of any system. Systems need to be able to reflect the variety of their environments (have 'requisite variety') if they are to live in some kind of homeostatic equilibrium. As complexity increases, so too must organisations – a point reflected in the move from hierarchical mass production to more network forms, matching the fragmentation of markets and the emergence of (often short-lived) opportunities (Harvey, 1990; Castells, 2010).

The VSM also provides a means of looking at system governance, to check that the necessary mechanisms and subsystems are in place to ensure that the system can detect and respond to environmental needs and disturbances. Governance is needed at all hierarchical levels, including – where it exists – at the inter-organisational level.

6 Discussion

6.1 Digitisation of network actors/vertices

We made the point above that digital technology is deeply embedded in various networks of social and economic relations. In systems terms, this reflects the fact that technologies, products, people and organisations can all be understood to exist in various *chains* of systems, what Beer calls 'recursive dimensions' (1985, p. 6). Each dimension is also organised by 'levels of recursion', *containing* systems (down, for example, to the cellular level), while being *part of*, wider systems – such as the broader organisation, or a more global social or economic structure (Ibid, pp. 4-5). For Beer, each of these can be understood as viable systems in their own right: they contain the cybernetic properties needed to maintain a separate existence. Put another way, a viable system (including all Systems 1-5 in Figure 1) can itself be seen as an *operational* component (a System 1) at a higher level of recursion. In terms of social network theory, each system (be it a person, group or organisation) is similarly understood as a *vertex* (or node), interacting with other systems via *relations* – or edges – with a range of relations being possible across different networks.

As we have said, each of these systems (or 'vertices') is likely to be penetrated by processes of digitisation, down to the artefacts used in production and operation, and the very product or service that is created (c.f. Yoo et al., 2010). Given the 'layered modular architecture' of digital technologies and artefacts, we have also noted that this produces a new *organising logic* (Ibid.). As traditional (closed) design hierarchies are replaced by more open, agnostic ones, we have also seen the erosion of industrial boundaries and the entrance of new actors able to reinvent the way value is created (entertainment being a classic example). This in turn led to an increase in processes of 'digitalisation' (Tilson et al., 2010), making digital technologies infrastructural as they become part of new organisational and institutional arrangements. The underlying technologies here are also increasingly powerful and compact, in terms of processing and broadband speed, and transistor density.

Taken together these developments have led to new generative dynamics, which have facilitated greater communication and collaboration across organisational boundaries. This can be seen at an artefact-to-artefact level (with the 'Internet of things'), as well as with the growth of inter-organisational networks –(Tapscott et al. (2000), for instance, identify five archetypal 'business webs'). They are also at the root of the 'combinatorial' innovations discussed by Brynjolfsson and McAffee (2014).

In VSM terms, these developments illustrate the increased openness of systems to operate across previously separate recursive dimensions and product design hierarchies, and thus the increased flexibility of systems to work together (be they artefacts, operating units or entire enterprises). New forms of organisational designs can thus result. However, these still need to allow for maximum autonomy and self-organisation at the local level (of recursion), while providing emergent properties – at the 'wider' system level – that help it to respond with requisite variety to the growing complexity of the environment. This therefore demands *integrative* activities (System 3 mechanisms), that ensure operational components (Systems 1) are appropriately resourced and articulated and that operational systems (be it a 'value chain' or a 'web') can act cohesively (Hoverstadt, 2008, pp. 97-9). In the absence of this, innovation components will not be 'combined' and the whole will be less than the sum of its parts.

For networked forms, this demands a shared sense of what the overall system is trying to achieve and what good performance looks like. Mechanisms used here might include: service level agreements, relationship contacts and quality criteria, which set out mutual obligations between parties. For open-source software developers and other voluntary communities it could simply be such mechanisms as a shared professional vision of what a quality outputs should look like. To meet the conditions of viability and stability, though, these systems – at whatever recursive level we choose to examine them – must also exhibit mechanisms for *coordination*.

6.2 Coordination in networks

That network communities, organisations and technical systems can be more resilient than those with a hierarchical arrangement at once makes sense, but also begs questions about how they get built in the first instance, and what structural elements must exist for the system to maintain order – or even grow. Such questions return us to the paradox mentioned above by Tilson et al. (2010, pp. 753-4) in the more specific context of digital infrastructure (that underpin network organisations and the broader network society). Such infrastructure, they noted, needs to be *stable* (to allow new actors and artefacts to join) but also *flexible* (to allow for 'unbounded' growth). This could be resolved, they suggested, via a *control point* (connections that help determine behaviours and constraints for other elements in the system). Tilson et al. give the example here of the iTunes platform, which simultaneously provides users with certain *rights* while also specifying particular *behaviours*. On the one hand, then, it is generative (in that it supports a vast number of users and applications), but it also restricts how users do this, via the app approval process, payment terms and architectural rules (Tilson et al., 2010, p.755). Similarly, they continue, defining an API that serves as the 'obligatory point of passage' provides users with the freedom to access a system while also laying down the basis on which this should be done.

In terms of the VSM (see Figure 1), we can see the importance of control points in the form of *System 2 mechanisms*, which support the 'coordination' of operations (the Systems 1). Such coordinating mechanisms, as Beer frequently points out, are critical for avoiding uncontrolled oscillations (for example, 1979, pp. 176-181) and thus help maintain the order of a system. Typical mechanisms here include protocols, mutual adjustment, boundary agreements, common standards, common language and culture (Hoverstadt, 2008, p. 84).

In theory, of course, hierarchical command could be used to micro manage participants (be they individuals, work groups or organisations), giving them detailed instructions on what to do, when and how. As well as being resource-intensive, such interventions would lack the requisite variety possessed by the actors themselves and otherwise rob them of their freedom to act. And in the context of networks of voluntary participants (such as programmers working on open-source software), hierarchical structures are unlikely to exist anyway. Coordinating mechanism thus help maintain system order and, as Tilson et al. illustrate, provide the means for further system articulation: other actors/vertices (Systems 1) can be added making use of the same control points.

For communities on the Internet, the importance of cultural factors (rather than hierarchical controls) as coordinating mechanisms is illustrated by the case of Jimmy Wales' *Wikipedia*:

> "While the system operators and server host – Wales – have the practical power to block users who are systematically disruptive, this power seems to be used rarely. The project seems to

> rely instead on social norms to secure the dedication of project participants to objective writing. So, while not entirely anarchic, the project is nonetheless substantially more social, human, and intensely discourse- and trust-based than other projects (as described in the book)." (Benkler, 2006, p. 72)

Whether in terms of cultural norms, technical interfaces or inter-firm agreements, the presence of these coordinating mechanisms help to explain the stability, articulation and growth of networks of various kinds. However, there is one final set of ideas we can explore that also helps to explain why networks can maintain themselves – and even expand – despite the lack of central leadership and command.

6.3 Digital network governance and autopoiesis

Governors, or homeostats, as we have said, are crucial to the regulation of systems, although this doesn't presume the presence of a 'ruler' or 'leader'. It is worth noting here that the words 'governor' and 'governance' in English come from the Latin 'gubernator', which in turn derives from the Greek 'kybernetes' – the word for 'helmsman' or 'steersman' that Norbert Wiener first drew upon in naming the discipline of 'cybernetics' (Hoverstadt, 2008, p. 269). Beer notes a special sub-class of homeostat that is concerned with the process of 'autopoiesis'. This draws on Maturana and Varela's work (see, for example, 1980), which has its roots in theories of biology (see also Morgan, 1997, pp. 253-256).

As Beer describes it (1975, p. 32), "An autopoietic system is a homeostat for which the critical variable held within physiological limits is *its own organisation"* (emphasis added). In literal Greek, the system is 'self-making' – it *produces itself*. And it is here that we perhaps can start to address Castell's (2010) call for a systemic framework. For Beer (1980), autopoiesis, like cybernetics, is nothing if not 'metasystemic'. As he points out in his guest preface to Maturana and Varela's *Autopoiesis and Cognition*, such theories are not merely *inter*-disciplinary; they are *trans*-disciplinary: they go beyond erstwhile theoretical boundaries to arrive at a new 'synthesis' (Beer, 1980, p. 66).

Such a synthesis is helpful not least in providing an ontological account of networked systems which addresses the 'inside-outside' issue – in that systems are not seen simply to reside in 'an environment', open in an uncontrolled way to its influence. Rather, as Beeson (2009) notes, an autopoietic system exists as "a network of relations and processes which continuously produce the components which realise that network as a concrete unity" (p. 185). Such a system is 'closed', in the sense that its behaviour is not specified or controlled by the environment, but rather by its *own structure*. As such – and citing Maturana and Verela (1987, p. 75) – Beeson notes that (autopoietic) systems should be understood as being in constant interaction with entities external to themselves though a process of 'structural coupling' (p. 185). The consequence of this reading is that:

> "...individuals and organisations are autonomous, not finally determinable nor controllable, and so are open, even within their structural constraints, to inexhaustible possibilities. (Beeson, 2009, p. 198)

Building on such insights – as well as on Beer's VSM work – Espejo and Reyes (2011) argue that organisations thus emerge when members of a collective produce a closed network of recurrent interactions and relations (p. 75). A closed network, they say, means that "the collective has decision rules and mechanisms to make up their own minds about relevant issues and produce, through their actions and decisions, a whole which maintains a separate existence" (p. 76). It is through these rules that people know who does and does not belong to the network and allows a domain of interaction to emerge as an organisation with its own identity. They go on:

> "This identity is produced when a particular set of organisational *relationships* is formed and therefore particular norms, values and meanings emerge as shared distinctions and practices that mediate individuals' recurrent interactions." (Espejo and Reyes, 2011, p.76)

It is System 5 of the VSM (policy) that ultimately deals with the regulatory activities bound up with identity – what the system is for and the balance it should strike between the 'inside and now' (what its operations are currently doing (Systems 1-3) and the 'outside and then' (how the system needs to develop and change to respond to its environment – a System 4 function). Where there is a strong sense of the organisation's purpose and driving values – as in many online communities – the system is likely to maintain its coherence and attract new members. Ongoing actions and interactions thus reinforce the system's meanings and values, allowing it to regulate and remake itself.

This might happen, for instance, as a community builds around releases of open-source software, where new developers join as the software is used and enhanced. Of course, sub-communities could also arise here, as 'forks' emerge that lead to different versions and applications of the software. Such networks would thus make use of the control points available in digital infrastructures to generate new combinations of relations (a System 4 'development' activity). This might happen via Open Source Project Management Systems (Bača et al., 2007), for example, or through domain ownership – leading to new forms of value to member communities and customers.

7 Conclusions

For IS researchers interested in networked structures these are important points. Autopoietic systems are able to survive without hierarchies and leaders. They can self-organise and self-regulate. They exist to 'produce themselves', to survive and perhaps to expand. By virtue of their reticular structure, they also exhibit the functional redundancy necessary to enable them to withstand shocks from the environment. But they can only do these things where critical variables are held within limits, which the presence of the cybernetic mechanisms enumerated in the Viable System Model help to achieve. And as Bača et al. (2007) point out, the IS that support them need also to be autopoietic in continuously adapting to the needs of users while also preserving their own characteristics (p. 160).

The digitisation of artefacts and architectures has opened up product design hierarchies and industrial boundaries. Where the requisite cybernetic mechanisms for viability are present, the generative capacity this has engendered has resulted in more open and fluid inter-organisational relations and thus a stream of combinatorial innovations, as well as (horizontal) Internet-based communities. For IS researchers, more focus on these inter-linked themes – networks, digital technology and cybernetic properties – should provide useful seams of insight for the increasingly digitised and networked society that lies ahead. This is particularly the case in terms of effective organisational design and the creation of new ways of working, but also in terms of the information systems that need to support them. Without a robust underpinning model of (networked) organisational structures and processes, it will be difficult to build effective IT-based systems to exploit the potential of the digital world.

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