A Transaction Byte Paradigm for Researching Organisations

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ABSTRACT

Transaction Byte Analysis (TBA) creates a methodology to analyze, evaluate and compare any human and/or non-human social systems. Any co-ordination between social creatures requires the creation, transmission, reception and internal processing of signals that can be measured in bytes. The neurological and/or physiological limits of creatures to process bytes can now be measured. TBA allows empirical evaluation to be made of the ability of creatures to cope with dynamic unpredictable complexity and/or coordinate their actions with others to sustain their existence to reproduce their specie. TBA fills a methodological gap for comparing control and communications in any individual and/or organizations.

Key words: Cybernetics, Governance science, Holon, System science, Tensegrity, Transaction Byte Analysis.

JEL Classifications: B41, C93, D0, D21, D22, D23, D72, D83, D87, L22.

1. Introduction,

This paper introduces a methodology grounded in the natural sciences for undertaking empirical research into the control and communications systems in any creature and/or their social system. The methodology is described as Transaction Byte Analysis (TBA) as bytes provide a common unit of analysis for any signals within and/or between creatures.

The potential for TBA to test organizational theories and the efficacy of various complex organizational architectures are illustrated by the development of hypotheses in the concluding Section.

No signal can be created, transmitted, received and acted upon without perturbations of energy and/or material. Any such perturbation that creates a "difference that makes a difference" (Bateson 1972) can today be represented in a binary unit described as a "bit" even when the difference may arise in an analogue form. Eight bits are described as a byte.

Humans can receive at least five different types of signals from their environment. These are the five senses of sight, sound, smell, touch and taste. While "The age of neural implants has already started" (Kurzweil 1999: 127) in the last century this possibility will be ignored in the following discussion.

Humans possess limited ability to transmit signals by consciously making changes in their taste and smell. In practice conscious transmission of signals is limited to sound, touch and other body movements. As the technology of neural implants is not yet widely adopted they can be neglected in current planning for empirical research.

At the end of the 20th Century it became technically possible to measure the physiological operating limits of humans to transmit and/or receive signals through their five natural senses. It has also become possible to identify the neurological limits of humans to process and store signals in their brains. The physiological and neurological limits of humans to process bytes are set out in Figure 1.

TABLE 1, Human Constraints in Transacting Bytes
(K= Kilobytes, M=Megabytes)

<table>
<tr><th>INPUT CHANNELS</th><th colspan="2">Smell</th><th>Taste</th><th>Touch</th><th>Sound</th><th>Sight</th><td rowspan="2">CONSTRAINTS IN HUMANS TO TRANSACT BYTES CREATED BY:</td></tr>
<tr><td>*Channel capacity in bytes/sec[a]</td><td colspan="2"><10</td><td><15</td><td><15</td><td>100K</td><td>1,000M</td></tr>
<tr><td rowspan="5">NATURE OF TRANS-ACTING BYTES IN HUMANS</td><td>1</td><td colspan="5">RECEPTION through organs</td><td>Physiology</td></tr>
<tr><td>2</td><td colspan="5">STORAGE through nervous system</td><td>Physiology</td></tr>
<tr><td>3</td><td colspan="5">PERCEPTION/UNDERSTANDING through the activation and strengthening of neural networks which correlate current patterns with previous ones</td><td>Neurology, experience, training, motivation and psychological status</td></tr>
<tr><td>4</td><td colspan="5">INSIGHTS/KNOWLEDGE through sequential processing in neo-cortex limited to around 200 calculations per second (Kurzweil 1999:103)</td><td>As above plus size and architecture of neo-cortex and psychological status</td></tr>
<tr><td>5</td><td colspan="5">EXTERNAL RESPONSES transmitted by movement and vocal chords</td><td>Proximity/distance, environmental conditions, culture, literacy & numeracy</td></tr>
<tr><th>OUTPUT CHANNELS</th><th colspan="2">Touch</th><th>Signs</th><th>Writing</th><th>Sound</th><th>Speech</th><td rowspan="2">Information can be received 10,000 faster than the rate at which it can be transmitted</td></tr>
<tr><td>*Channel capacity in bytes/sec</td><td colspan="2"><15</td><td><15</td><td><15</td><td><100K</td><td><100K</td></tr>
</table>

*Source of channel capacity: Cochrane (1997; 2000)

Visual information can provide data inputs four magnitudes higher than sound. Sound can provide data inputs one order of magnitude greater than touch, taste and smell. Human communication output channels are limited to only 100 Kilobytes per second. However, unlike even the most elementary personal computer today the ability of humans to sequentially process data is just 200 calculations per second (Kurzweil 1999: 103). Personnel computers at the time of writing can sequentially undertake millions of calculations per second. However personal computers are only just obtaining the ability to reliably recognize speech and faces. Unlike simple personal computers the human brain can process a massive number of bits of data in parallel rather than just sequentially. "The number of neurons in the human brain is estimated at approximately 100 billion, with an average of 1,000 connections per neuron, for a total of 100 trillion connections" (Kurzweil 1999: 119). This allows the human brain to out perform simple computers in recognizing patters that make up speech and images.

It is through pattern recognition rather than by logical sequential data processing that allows humans to currently compete with personal computers. Young children, or a dog, can undertake a complex task like catching a ball. Robots currently have difficulty in achieving this task. This is because a robot would need to be programmed with complex differential equations to anticipate the trajectory of the ball with manifold data inputs such as the initial trajectory of the ball, the weight and size of the ball, air temperature, air density, the co-efficient of friction of air with the ball, spin of the ball, wind speed and direction, the force of gravity, etc. Pattern recognition allows children and animals without such knowledge and data to catch balls. Pattern recognition provides one rationale for the case study method of teaching MBA students.

While the volume of data transmission and storage can be measured or estimated within and between creatures it is not possible to quantify information, knowledge and wisdom. The word "knowledge" is used in the sense to mean information that is useful for a human brain to use for either thinking or taking action. The word "wisdom" is used to describe a person who obtains the knowledge of when best to use knowledge. Because information cannot be physically quantified neither can knowledge or wisdom. However, the crucial point remains that no change in the quantity or nature of information, knowledge and wisdom can occur without the transaction of bytes. This makes bytes a fundamental unit of social analysis.

The non-commensurability of information arises because it represents data that provides meaning to a recipient. In the case of humans, the conversion of data into meaning depends upon the circuitry of the brain. Even identical twins have different neurological architecture because this is a product of both nature and nurture. While twins may have a shared DNA the way their brains develops is dependent upon random external stimuli. The need to occupy different physical positions is sufficient to generate different changes in the development of their neurological circuitry. However, in practice, cultural conditioning of quite different individuals can lead to the same data generating a shared meaning among many individuals.

So in practice it may become accepted that specified patterns of data can also indicate a specific volume of information even if it cannot be measured. Morse code is an example where conditioning allows humans with quite different cultures to learn to recognize specific patterns of dots and dashes. The patterns represent letters of the alphabet to create words that *may* possess a common shared meaning. For example, the letters SOS can be transmitted in Morse code with a pattern of six dots, three dashes and eight spaces. The letters SOS is a way of expressing an urgent need for assistance as originally the letters were used to communicate the phrase “Save Our Souls”.

Because shared meaning of words is commonly assumed, the word information is used as if it can be quantified. A common example is references to “information overload”. This ambiguity in the use of the word will be accepted without qualification to allow the citation of scholars. For example, Williamson (1985: 283) a 2009 Nobel Prize winner in economics stated: “The problem of organization is precisely one of decomposing the enterprise in efficient informational processing”.

Williamson recognized the economic importance of using data as a unit of organizational analysis. He stated: “But for the limited ability of human agents to receive, store, retrieve, and process data, interesting economic problems vanish” (Williamson 1979: note 4). Notwithstanding this insight Williamson adopted the social construct of cost as his unit of analysis to establish a methodology for the analysis of firms that he described as Transaction Cost Economics (TCE). However, not only are costs a social construct not subject to physical measurement and evaluation, they vary in nature between being an initial fixed set up cost and a variable operating component. The allocation of costs between those considered fixed and variable can be a matter of discretion for the analyst.

Evidence that TBA fills a methodological gap in organizational analysis is next considered in outlining the Science of Governance (Turnbull 2002; 2008). The third section introduces the architecture of complexity in physical, biological and social structures and how TBA provides a methodology for testing hypothesis concerning complex organizational structures. The fourth section provides examples of complex organizations and related concepts. Suggestions for investigating complex organizations with TBA are provided in the concluding section five.

2. Science of Governance

This section provides evidence of how TBA makes a methodological contribution by grounding social analysis in the natural science of cybernetics to establish a science of governance.

Norbert Wiener (1948) defined cybernetics as the "Science of control and communications in the animal and the machine". Stafford Beer (1966) pioneered the application of cybernetics principles to management that became described variously as "operations research", "management cybernetics", "management science" or "system science". As the President of the World Organization of System Science and Cybernetics in 1996 Beer informed me that neither he nor his colleagues had applied the science of control and communications to the governance of organizations. This advice was given after reading a Toronto conference paper that was later published with the seminal contributions of scholars as Turnbull 2000a.

From 1970 to 1973 Beer had worked for President Allende in Chile to establish a system of control and communications to operate a socialist economy using Teletype printers. So while Beer had applied the principals of cybernetics to coordinating firms this had been organized through a top down control and communication system as found in socialist economies and hierarchical firms. As Beer (1966: 263) points out: "viable systems cannot be entirely regulated from outside". For this reason, centralized hierarchical command and control systems are not found in nature. Our brains do not possess a "Chief Executive Officer neuron" (Kurzweil 1999: 84).

One widely known contribution of Beer was his concept of organizing units of a firm into "viable systems" to efficaciously manage complex tasks. This contribution was based on conceptual rather than quantitative cybernetic analysis and was limited to operations within a firm below the level of the board of directors.

Quantifying the ability of humans to receive, store, process and transmit data was only achieved at the turn of the last century. The then head of the British Telecom Research Laboratories Peter Cochrane (2000) quantified the physiological limits of individuals to receive and transmit data in terms of bytes as is set in Figure 1. MIT based voice recognition scientist Ray Kurzweil (1999: 103) reported the limitations of the human brain to sequentially process data in terms of bytes as noted in the centre of Figure 1.

In the current century the digitization of communication is becoming ubiquitous. The quantification of organizational communications becomes automatic as they are recorded, transmitted, processed and stored in various electronic devices. This provides a basis to utilize TBA to investigate how individual and organizations manage complexity. However, this opportunity has not yet been developed by social scientists even though many are dissatisfied with their current intellectual tools and methodologies.

For example, Radner (1992: 1384) stated: “I know no theoretical research to date that compares the relative efficiency of hierarchical and non-hierarchical organizations within a common model”. While Demb & Neubauer (1992) expressed concern that there was no way to “compare systems of corporate governance within and between cultures”. TBA provides a way to overcome both limitations because bytes are not dependent upon organizational architecture or culture.

In regards to firms, Winter (1991: 179) referred to the, "present theoretical chaos". Chaos was noted by Kuhn (1970: 77) as a "...precondition for the emergence of novel theories..." Williamson (1991: 11) stated: "Winter, like Demsetz, also emphasizes the importance of knowledge acquisition and its utilization in future work on the theory of the firm". Williamson (1990: xi) supported the suggestion by Simon (1984: 40) that theorists should, "find techniques for observing the phenomena at a higher level of resolution". He then poses the question, "How micro is micro?" TBA provides and answer to this question and also answers the concern of Demsetz. Demsetz (1991: 159) saw the need for: "a more complete theory of the firm must give greater weight to information cost than is given either in Coase’s theory or in theories based on shirking and opportunism which have not gone far enough".

While TBA does not measure costs, costs in Coase’s theory arise from “price discovery” for a businessperson to undertake make or buy a decision. In other words Coase posits that firms exist because of the cost of getting information to buy a component instead of making the item. Williamson (1979) developed a theory of a firm and its internal structure as an authority system using TCE. In modern complex information and knowledge intensive firms costs become a proxy for bytes. In the words of Kuhn (1970: 80) TBA "involves the same bundle of data as before, but placing them in a new system of relations with one another by giving them a different framework".

Price discovery has little meaning unless data is also transacted to associate the price with the many qualitative factors describing the type of goods and/or services and other costs involved. As bytes require perturbations in matter and/or energy the existence of firms could be explained by TBA as a way of minimizing the transaction of bytes and so the need for energy and/or materials (Turnbull 2001).

Jensen (1993: 873), an author of agency theory widely used in corporate governance analysis observed: "we're facing the problem of developing a viable theory of organizations". While the emergence of network firms led Zingales (2000) to state in regards to existing theories of the firm that: “they seem to be quite ineffective in helping us cope with the new type of firms that are emerging”. Some network firms are not based on control hierarchies on which theories of the firm are based. Network governed firms are subjected to a division of powers to provide checks and balances and a variety of independent control and communication channels. Some networked governed firms have adopted an ecological form of governance architecture as found in nature. These are described in the following section.

TBA not only provides a methodology for analyzing any type of firm but any type of social organization within and/or between specie. It makes possible an analysis of corporate governance that is fundamentally concerned with issues of communication and control within control centers/boardrooms and between firms and their stakeholders.

The word governance is derived from the Greek word “to steer”. It is the same Greek word that Wiener (1948) used to coin the word “cybernetics”. TBA provides methodology for extending the science of cybernetic from the control and communication in the animal and machine to include organizations. The science of governance can be defined as being concerned with the control and communications in the animal, machine and social systems.

The science of governance provides a new way for explaining how complex living things arose in nature as articulated by Simon (1962) and how to evaluate, design and/or regulate complex organizations. These issues are developed in the following section that introduces the architecture of complexity.

3. The architecture of complexity

This section uses TBA to provide insights into the architecture of complexity found in nature and to explain the operating advantage of social organizations adopting ecological forms of governance rather than command and control hierarchies.

Henry Simon (1962) in his seminal lecture on the architecture of complexity used probability analysis to explain how nature could create the complexity of life. Simon explicated how nature creates and controls complexity by what he described as: “sub-assemblies” (1962: 472) or “stable intermediate forms” (1962: 473) to create “nearly decomposable systems, in which the interactions among the sub-systems are weak, but not negligible” (1962: 474). These “sub-assembles”, “forms” and “sub-systems” were given the name of “Holons” five years later by Koestler (1967).

While the name Holon has been widely accepted by many scholars, others have used their own terminology. This has held back development of the concept that was first noted perhaps by Jan Smuts (1926) a former Prime Minister of South Africa and a Field Marshal who described them as “wholes”. Biologist Ludwig von Bertalanffy (1955) used the term “systems”, Ralph Gerard (1957), a neurophysiologist used the term “org” while Stafford Beer (1966) described them as a “viable system”. David Bohm (1980), a quantum physicist referred to “relatively independent subtotalities”, Czech engineer Joseph Hatvany (1985) used the word “entities”, Duffie (1990), another engineer refers to “heterarchical cooperation” in computer-controlled manufacturing. The founding CEO of the credit card company VISA international, Dee Hock (1999) combined the words “chaos” and “order” to create the term the term “Chaord”. Harvard Business School scholars Carliss Baldwin & Kim Clark (2006) used the terms “module” and “capsules”.

Arthur Koestler describes a hierarchy of holons as a “holarchy” to distinguish it from a hierarchy where there is a direct “boss” (Simon 1962: 468) in a command and control system. Beer (1972: 69) used the term “metasystemic” to describe a group of viable systems. As Mathews notes (1996: 47), “Once attuned to the structure of holonic architecture we see them everywhere.” They are ubiquitous in biological structures and are now used in the design of complex object orientated software and robotic control systems.

In reporting on the design of Japanese robots, Mathews (1996: 30) reported: “The reduction in data transmission, and in data complexity, achieved by the holonic architecture is prodigious. Moreover the advantages accumulate as the robotic device gets more complex”. The prodigious reduction in data quantity and complexity provides one compelling explanation of the operating advantages of complex social organizations that adopt holonic architecture. TBA provides a methodology for investigating data complexity and variety in any type machine, creature or social organization.

Examples of complex firms that have adopted ecological forms of governance are the credit card company VISA International in the US, The John Lewis Partnership that is one of the largest retail stores in the UK and the nested networks of network governed firms in Northern Spain that are collectively known as Mondragón Corporacion Cooperativa (MCC). The geographical diversity of these three large-scale examples proves that special laws are not required for organizations to adopt constitutions to introduce a holonic organizational architecture.

The operational advantages of ecological forms of governance do not just arise from reducing data overload for individuals of the organization. Strong holonic structures also generate a rich variety of control and communication circuits to manage/monitor complexity. The ability of ecological governance to generate a requisite a requisite variety of control (Ashby 1956) and communication (Shannon 1948) circuits arise from holonic structures possessing “Centralization and decentralization of control” (Mathews 1996: 41). Buckminster Fuller (1961) described physical structures made of up components with such contrary characteristics as possessing “tensegrity”.

Fuller coined the word “tensegrity” from contracting the words “tension” and “integrity”. He was inspired by the structures created by artist Kenneth Snelson (Hearney 2009) that led Fuller to design geodesic domes and other structures. Fuller described tensegrity structures as 'islands of compression in an ocean of tension'. René Motro (2003: 12) defined tensegrity as: "systems in a stable self equilibrated system comprising a discontinuous set of compressed components inside a continuum of tensioned components".

Donald Ingber (1998) described tensegrity as "The architecture of life" because biological structures depend upon materials with contrary properties. An example is the human body constructed of bones that function as compression components and muscles that function as contrary tensional components. Complexity in the architecture of the universe arises from the emergence of more complex components from simpler components with contrary properties. For example electrons with a negative charge combine with protons with a positive charge to create a new more complex structure called an atom. Atoms are created with various numbers of electrons to allow atoms to combine in numerous combinations to create various molecules that in turn produce emergent properties not found in their components.

Table 2 reveals how the complexity of the universe arises form simpler components with different properties. Humans and entities of the MCC are shown to be part of this universal process in rows 8, 10 and 11.

Table 2, Holarchy: Hierarchy of Holons

Complexity of the universe arises from emergent properties arising from simpler components that possess contrary characteristics (i.e. posses tensegrity)

In: nature rows 1–7, society rows 8–13, and engineering rows 14 and 15

	Discipline/Subject	First level	Second level	Third level
1	Physics	Particles	Atoms	Molecules
2	Chemistry	Molecules	Compounds	Bases
3	Genetics	Bases	DNA	Genes
4	Biology	Genes	Chromosomes	Cells
5	Anatomy	Cells	Organs	Individuals (Creatures)
6	Environment	Biota	Ecological systems	Ghaia (Earth)
7	Astronomy	Earth	Solar system	Galaxy
8	Sociology	Individuals	Families	Communities
9	Organisations	Autonomous cells/divisions	Firms	Keiretsu /groups
10	Mondragón Co-op	Work groups	Social council	General assembly/co-op
11	Mondragón system (MCC)	Co-operative	Cooperative groups	Mondragón Corporación Cooperativa (MCC)
12	VISA Card	Geographic unit	Member bank	VISA International
13	Government	Communities/towns	Regions/States	Nations
14	Engineering	Components	Sub-assemblies	Machine
15	Software design	Sub-routines	Routines	Object-orientated programs

Philosophers have long recognized that humans have contrary ying/yang type of behavior. Contrary approach/avoidance behavior is commonly observed in animals. Humans can also be suspicious/trusting, competitive/cooperative, selfish/generous, self-interested/altruistic and so on. In this way humans can generate a requisite variety of responses to learn how to sustain their existence in unknowable complex environments.

If humans were not hard wired by their DNA to possess contrary behavior, their DNA would need to be much more complicated to program their behavior to take into account countless combinations of unknowable complex life threatening environments. Behavioral tensegrity can be seen as an evolutionary strategy for the amplification of variety through a process that Ashby (1956: 231) describes as "supplementation".

In other words, contrary behavior is a way for evolution to provide creatures with a requisite variety of responses to reproduce their DNA while minimizing the size of their DNA. Likewise, Buckminister Fuller explained that geodesic domes constructed of materials with contrary characteristics could cover the largest area with the minimum quantity of material. In organic structures Ingber (1998: 32) explained the role of tensegrity as providing "a maximum amount of strength for a given amount of building material". Turnbull (2000b: 134) put forward the hypothesis that "social tensegrity" provides " a maximum amount of control (strength) for a given amount of bytes (building material)". TBA provides a methodology for empirically testing this hypothesis. Another related hypothesis is that social tensegrity provides a requisite number of responses to manage uncertainty while using minimum energy and/or materials to transact bytes (Turnbull 2000b: 134).

In other words social tensegrity in organizations maximizes their ability to self-control/self-regulate/self-govern with the minimum transaction of bytes (Turnbull 2000b: 118). Minimizing bytes means minimizing perturbations in matter and energy and so costs. This in turns explains how network governance can provide competitive advantages and resiliency compared with hierarchies that create information overload, and a lack a requisite variety of communication and control channels to reliably control/regulate complexity. The operating and/or competitive advantage of network organizations increases as activities increase in complexity (Craven, Piercy & Shipp, 1996; Jones, Hesterly & Borgatti, 1997).

Jones et. al (1997: 914) limited their definition of "network governance" to a network of firms. Their definition excluded distributed control within a firm or between a firm and its controlling shareholders. The concept of a "compound board" defined in Turnbull (2000b: 1) allows network governance to include firms controlled by more than one board internal and/or external to a firm. As a majority of listed corporations possess a controlling shareholder (Porter, Lopez-de-Silanes & Schleifer 1999) the majority of listed corporations have network governance with a compound board. However, this phenomenon is ignored by scholars undertaking "normal science" that does does not "call forth new sorts of phenomena: indeed those that will not fit the box are often not seen at all" (Kuhn 1970: 24).

Hierarchies depend upon obedience and conformity. In this way hierarchies inhibit the ability of individuals to act in a contrary manner as encouraged by their DNA. Hierarchies inhibit the ability of individuals to consider a requisite variety of responses required to mitigate risks and exploit opportunities. This problem was identified by Hock (1995: 4) who stated:

> Industrial Age, hierarchical command and control pyramids of power, whether political, social, educational or commercial, were aberrations of the Industrial Age, antithetical to the human spirit, destructive of the biosphere and structurally contrary to the whole history and methods of biological evolution. They were not only archaic and increasingly irrelevant; there were a public menace.

Hock (1999: 6) observed before the financial crises of 2008 that:

> We are experiencing a global epidemic of institutional failure that knows no bounds. We must seriously question the concepts underlying the current structures of organization and whether they are suitable to the management of accelerating societal and environmental problems – and, even beyond that, we must seriously consider whether they are the primary source of those problems.

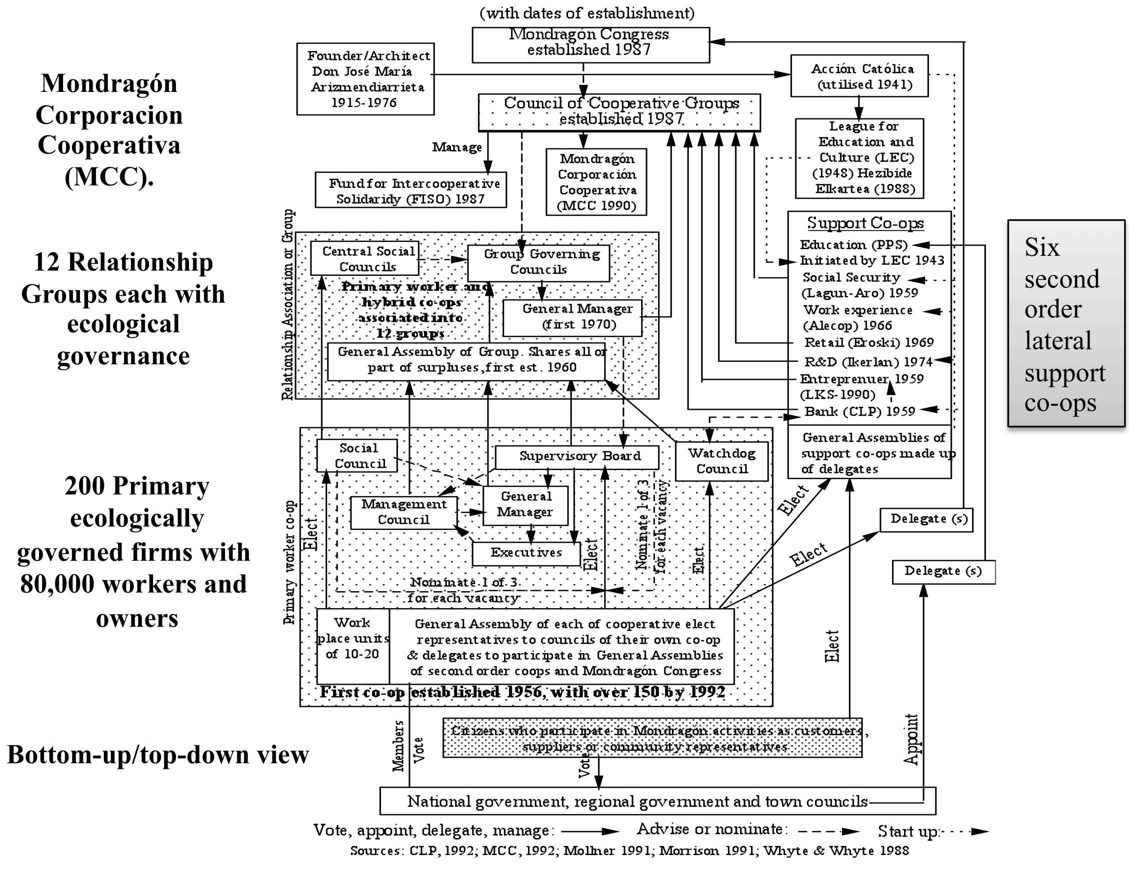
The US *Financial Crisis Inquiry Commission Report* concluded that "a key cause of" of the 2008 crisis was a failure of corporate governance (FCICR 2011). Turnbull & Pierson (2012) provided evidence that the failure of governance arises because of top down centralized hierarchies deny systematic feedback channels between individuals who have knowledge of risks who are also connected with individuals with the incentive and power to act to mitigate risk. In short, centralized "pyramids of power" have created a form of high risk alienating disconnected capitalism. Network governance can be designed to fill in the disconnections. TBA with the science of governance provides design criteria for designing the connections and testing the results. Alternative forms of governance that provide opportunities for operating and social advantages are next considered.

4. Ecological governance

The section provides an example of ecological governance, which is a special form of network governance that follows the architecture of nature. The example is used to suggest how TBA could be used to investigate and compare complex forms of governance with firms that have simpler centralized command and control architecture that is dominant in modern societies.

The eye glazing mind numbing complexity of the MCC control and communication architecture illustrated in Figure 1 decomposes decision-making labor into simpler elements that are widely distributed through all members of the firm. This also introduces a greater variety of control and communication channels to increase their accuracy and resilience while providing distributed intelligence to harvest and act on knowledge of risks and opportunities on a decentralized basis. Governance and management functions become so highly distributed that they become merged and shared by all members. Figure 1 was developed for a MCC case study (Turnbull 1995) and has been updated with comments to the left and right of the Figure. Additional detailed discussion of Figure 1 is provided in Turnbull (2000b: 199-225).

Figure 1, Holarchy of ecologically governed MCC firms, their groups and lateral support firms



It is by increasing organizational complexity that counter intuitively the data processing workload of individuals can be simplified to allow ordinary individuals to achieve extraordinary results with impressive resiliency in “both favorable and adverse conditions” (Thomas and Logan 1982: 127). Ballantyne (2011) updates the sustainable success of the MCC by reporting that after the 2008 Global Financial Crisis that: “Mondragón worker co-ops ride out global slump”.

Figure 1 shows that the MCC system is composed of almost 200 primary cooperatives with each firm having the ability to exist independently of the whole system. Only a few firms have left the system but that they can proves the point and shows that there are persuasive advantages of being in the MCC system. Primary coops represent what Simon (1962) described as: “sub-assemblies”, “stable intermediate forms” and meet the other tests of being a holon. That is they possess “Relative automony”, “system dependence”, “concatenation: recursivity” and “no part of the system will possess complete information about any other part” (Mathews 1996: 39-40). The existence of this last point was confirmed in VISA by Hock (1994: 7) who stated VISA: "has multiple boards of directors within a single legal entity, none of which can be considered superior or inferior, as each has irrevocable authority and autonomy over geographic or functional area".

The MCC system grew by creating new firms and from larger member firms spinning off part of their operations into a supplier or customer organization. Most of the expansion was from this process that mimics an amoeba. The 200 firms in the MCC are controlled in 12 groups with each group having its own ecological governance. The groups are governed by a meta-level holon at the top of the holarchy created by the MCC system.

Besides the primary cooperatives there are “lateral” second order cooperatives that service the primary cooperatives and their members. The support firms provide banking, insurance, social security, research and development, education and retail services. Each of the lateral support firms adopts the ecological form of governance of the primary cooperatives. The holon concept allows the complexity of the whole complex MCC system to be parsimonious presented as shown in Table 3.

Recursivity economizes the transaction of bytes by providing a common template for constructing new components. Highly complex fractal structures can be generated from simple “process information” (De Vany 1998: 3) that may take only a dozen or so bytes. This is illustrated by common fractal formulas like Z=Z squared plus C that lead to highly complex patterns. But the bytes required to describe the result with “state information” (De Vany 1998; 7; Simon 1962: 479) can be many orders of magnitude greater.

The ability of ecological governance to economize the transaction of bytes is illustrated by considering the workload on individual members of a centralized governed organization with a unitary board with the workload of individuals on the many boards in a Mondragón firm. The roles of directors of a unitary board are shown in Table 4.

Table 3, Holon typology of Mondragón

Concatenated holons creating a Holarchy		Integrity holons assure coordination and support of all component holons in the system (with recursive intra-support)	Integrity holons internal structure possess lateral recursivity
Productive	Intra-support vertical recursivity		
80,000 Individuals	Biological components: (brain, nervous system and other support organs)	Cultural imprinting (Hezibide Elkartea); Schooling (EPP); Social security (Langun-Aro) Retail store (Eroski) Retail banking (CLP)	General Assembly Work groups Social Council Supervisory Board Watchdog Council
200 Firms	General Assembly Work groups Social Council Supervisory Board Watchdog Council	Trade and professional schools (EPP) Work experience (Alecop) Wholesale banking (CLP) R&D (Ikerlan)	General Assembly Work groups Social Council Supervisory Board Watchdog Council
12 Groups or 'Relationship Associations'	General Assembly of groups Group Social Council Group Governing Council	Entrepeneur and imprinter of 'holonic architecture' (LKS)	General Assembly Work groups Social Council Supervisory Board Watchdog Council
Mondragón Corporación Cooperativa	Mondragón Congress Central Social Council Council of Groups	Fund for Inter-cooperative solidarity	

Table 4, Functions and activities of a unitary board
(Source: Tricker 1994: 245 & 287)

	Conformance functions	Performance functions
External	*Accountability* • Reporting to shareholders • Ensuring statutary regulatory compliance • Reviewing audit reports	*Strategic thinking* • Reviewing and initiating strategic analysis • Formulating strategy • Setting corporate direction
	Appointment and rewarding chief executive	
Internal	*Supervision* • Reviewing key executive performance • Reviewing business results • Monitoring budgetary control and corrective actions	*Corporate policy* • Approving budgets • Determining compensation policy for senior executives • Creating corporate culture
	Short term	Long term

Table 5 shows how decision-making labor is decomposed and distributed to all members of the firm by having a different control centre/board for each of the five segments shown in Table 4. An X is used to indicate how many bytes are required to undertake each function of Table 4 is distributed through the five boards in Table 6. TBA provides a way of quantifying X for each person in each

MCC board so as to compare the number with data processing load with directors of a unitary board.

Table 5, Functions and activities of Mondragón compound board

(Information source: Whyte & Whyte 1988)

	Short term	Long term
External	*Watchdog Council* (Invites external intervention by bank and/or Group)	*Supervisory Board* (Strategic stakeholders appoint & direct management board)
	Management board **(Allocates resources)**	
Internal	*Work Unit* (Production & appoint delegates to Social council)	*Social Council* (Working conditions, pay relativities and welfare)

Table 6, Mondragón compound board compared with unitary board

(Degrees of decomposition of information processing labour indicated by allocations of "X")

Board type⇒	**Mondragón "compound board"**					**Anglo**
Control centres[a]	Watchdog Council	Supervisory Board	Management Board	Social Council	Work Unit	Unitary Board
Members	3	5-8	4-6	~5-25	~10-20	~4-12
Function[b]	Governance processes	Appoint Mgt. board	Organise operations	Worker welfare	Production, Elect Soc.C.	Manage
Activities	Efficacy & integrity of processes	Integrate strategic stakeholders	Efficient allocation of resources	Establish working conditions	Job organ-isation & evaluation	Direct & control
Internal[b]	X		X	X	X	XXXX
External[b]	X	X				XX
Short term[b]	X		X		X	XXX
Long term[b]		X		X		XX

[a]Omits the General Assembly, which elects Watchdog Council and Supervisory board.
[b]Descriptions follow typology of Tricker (1994: 244 & 287)

Given the limited ability of humans to process data as shown in Table 1 the ability of individuals to cope with their data processing load in each situation could also be estimated. Content analysis of the data could be used to estimate the amount of information related to the data processing load of members of the various control centers and/or boards. In this way the operating conditions of ecological governance and management could be compared and evaluated with the dominant centralized systems of governance and management. Another parameter that could be measured and compared is the variety of data sources used in the control and communication systems of both types of governance architecture.

5. Concluding remarks

To attract researchers and/or their PhD students to pioneer quantitative investigation into ecological forms of governance some hypothesis are suggested below. The hypotheses are based on using TBA to quantitatively evaluating and comparing firms with a dominant form of centralized governance and management with those with ecological forms of governance and management.

H1. Decision makers in network governed/managed firms like The John Lewis Partnership in the UK or the Mondragón Cooperative system in Northern Spain obtain a greater variety of information on their Strengths, Weaknesses, Opportunities and Threats (SWOT), than firms organised as command and control hierarchies as listed on stock-exchanges.

H2. The simplification of data/information processing by members of an organization requires an increase in its organizational complexity from increases in the number of independently established decision-making centres and channels of communications and control (i.e. creation of "network governance").

H3. Individuals in network-governed firms share a greater variety of contrary information than those in command and control hierarchies.

H4. The operating and competitive advantages of network-governed firm's increases with the variety of its undependably established decision-making centres, communication and control channels.

H5. Social tensegrity creates the greatest variety of communication and control channels with the least energy and/or materials.

As the dominant form of modern social institutions in the public, private and non-profit sectors are centralized command and control hierarchies, application of the insights of governance science would introduce a profound change in the power structures of society. The need for such fundamental changes is steadily increasing with the accelerating complexity of society.

Not only are large complex corporations becoming too big to fail they are also becoming too big to manage, govern and/or regulate as investigated by Turnbull and Pirson (2012). The manifold benefits of introducing a resilient and sustainable ecological form of governance are set out in Turnbull (2013) for shareholders, governors, directors, management, auditors, regulators and stakeholders. The impossibility of amplifying control without supplementary regulators as identified by Ashby (1958: 265) should force governments to require corporate constitutions to make provision for sharing corporate powers with the stakeholders that governments makes laws and establish regulators to protect. In other words the license for firms to exist should depend upon firms becoming responsible for their own regulation and social responsibilities.

The test of good governance would then depend upon the degree that firms could reduce the need for complex laws, regulators, lawyers, courts, listing rules and codes of behavior. In other words good governance would be achieved by maximizing self-governance to minimize the role of role of government. Good governance would then depend upon adopting ecological forms of governance. This would not only reduce the role of government but also enrich democracy because good governance would depend upon the active engagement by firms with a requisite variety of their stakeholders.

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