Grounding Sociology in System Science

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ABSTRACT

This paper uses Transaction Byte Analysis (TBA) to ground sociology in system science. No relationship or organisation can exist without some sort of communication that can be measured in bytes. The transmission or storage of bytes involves physical changes in materials or in energy states subject to scientific laws. Information overload and bounded rationality can be explained by the physiological and neurological limits on the ability of individuals to receive, store, process or communicate bytes and so information, knowledge and wisdom. The laws of requisite variety in communications, control and decision-making provide additional criteria for evaluating and/or designing social systems and organisations with unreliable components.

The power of TBA is illustrated by showing how the nested network of firms around the town of Mondragón in Spain follows the strategies used in nature to create and manage complexity through simple components. Unlike many other organisational theories, TBA accepts that individuals can be either, or both, trusting/suspicious, cooperative/competitive and/or altruistic/selfish. TBA is compared with Transaction Cost Economics (TCE) which it subsumes when costs represent a proxy for information. Unlike TCE, TBA can be applied to any type of social institution to provide the foundations for a "science of organisation".

Keywords: Holons, Mondragón, Requisite variety, Science of organisation, Self-regulation, Social architecture, Tensegrity, Theory of the firm, Transaction byte analysis, Transaction Cost Economics.

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Grounding Sociology in System Science

1. Introduction

This paper shows how a framework described by Turnbull (2000c, 2002b,c) as Transaction Byte Analysis (TBA) can ground sociology in system science. Bytes provide a universal unit of social analysis. No relationship or organisation can exist without some sort of communication that can be measured in bytes. The transmission or storage of bytes involves physical changes in materials or in energy states that are controlled by the laws of nature (Turnbull 2002b,c). Information overload and bounded rationality can be explained by the physiological and neurological limits of individuals to receive, store, process or communicate bytes and so data, information, knowledge and wisdom. The rates at which humans can receive, process, store and transmit bytes can be quantified as reported in Turnbull (2000c,f, 2001a,b, 2002b,c) to provide guidelines to evaluate, compare or design organisations and relationships.

The physical limit of an individual to transact bytes restricts their ability to manage complexity. The laws of information and control identify additional limits for managing complexity. But they also identify organisational strategies found in nature that can mitigate this problem.

The need to decompose complexity into simpler tasks to overcome information overload and "bounded rationality" (Hayek 1945: 527) provides one explanation as to why firms exist (Turnbull 2001b). It can also explain the internal information and control architecture[1] of an organisation.

For example, organisations commonly limit the number of subordinates reporting to a superior to dozen people or less to avoid information overload. The repetitive application of this limited 'span of control' to the subordinates of subordinates explains the formation of hierarchical organisations.

However, individuals are subjected to biases, errors and mistakes in processing or communicating information (Downs 1967: 116–8). The cybernetic laws of requisite variety for improving the reliability of information, control and decision making with unreliable components requires that hierarchical organisations be replaced with networks to provide "requisite variety". Unlike the subservience and discipline required in command and control hierarchies, network organisations allow the contrary ying and yang nature of individuals to emerge of being self-interested/altruistic, suspicious/trusting, competitive/cooperative and so on.

The combining of opposite properties in the macro[2] physical world is described as "Tensegrity" (Fuller 1975) and is used in nature to provide "a maximum amount strength for

[1] In relation to organisations, the word "architecture" in the corporate finance literature may have a different meaning as described by Smith (2001: 1). Smith uses the phrase "organizational architecture" "to refer to three key aspects of the firm: (a) the assignment of decision rights within the organization, (b) the structure of systems to evaluate the performance of both individuals and business units, and (c) the method of rewarding individuals. In this article the word architecture in regards to social institutions is concerned only with the assignment of decision rights incorporated into the constitution of the organisation and the network of communications channels that this creates. These information and control channels represent a cybernetic architecture.

[2] In the "micro" physical world of quantum physics opposite properties are combined together. For example light can behave as both a particle and as a wave. This is described as "complementarity" that Jungian psychologists compare with the conscious and unconscious mind <http://www.integralscience.org/psyche-physis.html#Heading4>.

a given amount of building material" (Ingber 1998: 32). Likewise, TBA posits that natural selection developed contrary behaviour in social animals to maximise social self-regulation while minimising communication to economise the transaction of bytes (Turnbull 2001a).

Network organisations that meet the test of being a "holon" introduce a prodigious "reduction in data transmission and in data complexity" (Mathews 1996: 30) and also like individuals, contrary characteristics such as "centralisation/decentralisation; bottom-up/top-down; autonomous/integrated; order/ambiguity" (Mathews 1996: 41). These antinomies explain why the words "chaos" and "order" were combined to create the word "Chaord" by Hock (1994) who apparently was not aware that he was talking about holons when describing the organisational form of VISA International that he helped to create.

Different scholars have described Holons by different names. Simon (1962) referred to them as "sub-assemblies" and "stable intermediate forms" while Ingber (1998: 30) called them "stable structures" and Beer (1985: 1) referred to them as a "viable system". Mathews (1996: 36, 38, 37) describes how von Bertalanffy called them "wholes", Hatvany described them as "entities", while Ashby described the cybernetic functions of what was later described as a hierarchy of holons. It was Koestler (1967) who coined the word "holon" and described a hierarchy of holons as a "holarchy" to explain how complexity is created throughout the universe as noted earlier by Smuts (1926) who referred to "wholes".

The power of TBA for investigating complex organisations is illustrated by showing how the nested networks of stakeholder controlled firms located around the town of Mondragón in Northern Spain follow the ubiquitous strategies used in nature for creating and managing complexity. TBA also provides a basis to explain the strategies of nature.

The nested networks of network firms that make up the Mondragón Corporacion Cooperativa (MCC) have been found to be more efficient then traditionally structured firms (Thomas & Logan 1982: 109). This is consistent with the statement by Mathews (1996: 51) that "networks enjoy competitive advantages over traditional atomistic hierarchical firms". TBA provides an explanation for the superior performance of the MCC. In the words of Mathews (1996: 30) it arises because "the reduction in data transmission, and in data complexity, achieved by holonic architecture is prodigious". In this way holons permit a prodigious economy of bytes in managing complexity.

In section two, the cybernetic characteristics of humans are identified. Section three identifies cybernetic laws and strategies found in nature that provides the most efficient way to create and manage complexity with unreliable components. Section four illustrates how complexity is created and managed in the MCC. The concluding Section shows how the TBA paradigm subsumes and extends Transaction Cost Economics (TCE) to allow any type of institution or social structure to be investigated.

2 Cybernetic operating characteristics of humans

This section identifies the cybernetic operating characteristics of people. The assumptions used by economists on how individuals behave can be quite different from the assumptions used by psychologists as illustrated in Table 1. Differences between "economic" and "real" people.

The processing of information is explicitly involved in rows 2, 6, 7 and 8 and implicitly involved in rows, 1, 3 and 4. Bounded rationality is created by the characteristics off real people shown in rows 2 and 9 while row 9 also explains information overload. The contrary nature of people is shown in rows 3 and 5. This contrary nature being exacerbated by the requirements of their internal state shown in rows 1 and 4 and from their external environmental feedback noted in row 7. The behaviour of people is dependent upon both the physiological status and their environmental feedback. In addition row 7 notes that different people can behave in different ways to make people both an independent and dependent variable.

Table 1, Differences between "economic" and "real" people

	ECONOMIC PEOPLE	REAL PEOPLE
1	Unlimited appetite	Appetite determined and limited by the necessity of maintaining the organism in a state of dynamic equilibrium.
2	Completely informed	Reduces, condenses, summarises (and thus necessarily loses) information. In addition, an 'imperfect' communications network in the environment also restricts and attenuates the flow of information.
3	Consistently orders his/her preferences between outcomes over time.	Does not consistently order his/her preferences (ie, changes his/her mind over time, may prefer A to B, B to C but C to A).
4	Maximises something (usually one thing).	Attempts to optimise with respect to a large number of criteria (needs).
5	Competitive	Sometimes competitive, sometimes collaborative, usually both.
6	Requires a value system only in order to provide a criterion against which to maximise (eg. profit, utility, prestige and power).	Requires a value system in order to provide a framework for the ordering of needs, the selection of information and the weighing of multiple decision criteria.
7	Not explicitly related to the world as an element in interactive system and remains unchanged as a result of any interaction.	Stands in an interactive cybernetic relationship to his/her community and environment and is changed as a result of any interaction.
8	No significant differences between individuals.	Differences between individuals are significant and important.
9	No limits on information processing capacity, so is unaffected by differences in rates of change.	Limited information processing capacity so prefers slow rates of change, (ie. nearly stable systems).
10	Needs are simple and few.	Needs are simple and many.

Source: Wearing (1973)

The term "bounded rationality" arises from Hayek (1945: 527) who noted that "the problem of a rational economic order is trivial in the absence of bounded rationality limits on human decision makers". Williamson (1975: 21) explains that:

> The physical limits take the form of rate and storage limits on the powers of individuals to receive, store, retrieve and process information without error. Simon observes in this connection that "it is only because individual human beings are limited in knowledge, foresight, skill and time that organizations are useful instruments for the achievement of human purpose", quoting Simon (1957: 199).

These observations also explain why information that can be measured in bytes provides the most fundamental unit for organisational analysis.

The comments by Hayek, Williamson and Simon quoted above support the view that it is information, rather than costs that provide a reason for organisations to exist for undertaking complex tasks. In other words, *firms emerge as way a way to reduce the number of bytes that individuals need to transact to co-ordinate complex tasks efficiently.* That is, firms emerge as a way to reduce bounded rationality and information overload. TBA provides an instrumental reason for the existence of firms (Turnbull 2001b). Firms may also emerge for other physical reasons that are also not based on costs such as to increase the physical effort as in team production (Alchian & Demsetz 1972) or allow services to be provided at all hours and/or in many ways that a single person can not.

Economic analysis is based on the normative assumption that the social construct of cost should be minimised. TBA is based on the instrumental requirement to minimise the transaction of bytes within and between individuals to recognise their physiological and neurological operating limits. While Coase (1937) used costs to explain why firms exist he was in effect using costs as a proxy for bytes to explain why markets fail to provide information in organising productive activities as efficiently as hierarchies. He stated that, "The most obvious cost of 'organising' production through the price mechanism is that of discovering what the relevant prices are. This cost may be reduced but it will not be eliminated by the emergence of specialists who will sell this information."

However, Coase, Williamson, and most other organisational theorists restrict their analysis to firms organised as a hierarchy with a unitary control centre or board. Williamson (1985: 265) excludes labour-controlled firms from consideration. All non-trivial sustainable labour controlled firms have more than one board (Turnbull 2000b). This presents a problem as identified by Radner (1992: 1384). He stated that "I know of no theoretical research to date that compares the relative efficiency of non hierarchical organizations within a common model". TBA provides such a model to compare organisations with two or more boards or control centres and so networks. It also allows firms with a single board to be compared with those with two or more boards that create a "compound board" (Turnbull 2000c,f) illustrated in Section five.

Inherent in the decomposition of decision making labour into a number of boards or control centres is the creation of distributed intelligence with a variety of information channels and system of control. The cybernetic implication of introducing variety in decision making, information and control is next considered.

3 Cybernetic laws and strategies for economising bytes

This section introduces three cybernetic principles that indicate why complex organisations governed by a central control centre is at a disadvantage in: (i) overcoming bounded rationality in decision making, (ii) obtaining sufficiently accurate information to make decisions, and (iii) exercising sufficient control to manage complexity.

Mathematician von Neumann (1947) identified the advantages of introducing variety in decision-making centres. He was one of the founders of the science of cybernetics and explained how the brain could obtain reliable results from unreliable elements. Beer (1995b: 448) described this as the von Neumann theorem, which states, "outputs of arbitrarily high reliability can be obtained from computing elements of arbitrarily low reliability if the redundancy factor is large enough". This observation is quite general and applies to social organisations. In organisations this means that errors in decision making can be diluted to irrelevance if there are sufficient number of decision-makers.

The von Neumann theorem explains why authoritarian management that does not accept a plurality of views has greater exposure to incorrect decision making. The theorem implies that a compound board, with diverse views of its stakeholder constituencies, and a plurality in its components, reduces the risk of sub-optimal decision making. This is independent of any motivational advantages that may be obtained by involving a greater number of people in decision making or decomposing decision making labour by using a compound board to introduce distributive intelligence.

Shannon, another pioneer of cybernetics, made a somewhat similar observation. Shannon (1949) showed that accurate information could be obtained, when noise, distortion and bias exist in a communication channel, by establishing a variety of information channels. Beer (1995b: 282) states:

> For example, if management were compelled to rely on the information it required through "orthodox" channels of communications, it would certainly never have anything like requisite variety for controlling the company – for the simple reason that the orthodox channels could not transmit it.

To correct for noise, errors, distortions and biases, a variety of independent channels of information are required. By having a variety of independent sources of information, the problems of lost or distorted information described by Downs (1967: 116–8) can be overcome as much as desired. The need for collaborating evidence is a common feature in many types of investigations and many CEOs establish informal information networks to supplement formal channels of reporting as indicated by Beer. However, idiosyncratic informal channels do not represent a systemic process for assuring the integrity of management information. Ways of establishing a variety of formal channels independent of management are described by Turnbull (1994, 1995a, 1997, 2000a,b,d,e,f, 2002a).

Both the CEO and directors of a unitary board are generally at a disadvantage in having access to systemic process for obtaining the “other side of the story” of any strengths, weaknesses, opportunities and threats (SWOT) in either management or the business. Hence the recommendations of Porter (1992: 16–7) to include diverse stakeholders in the information system of firms to provide competitive advantages. However, the inclusion of diverse stakeholders on a single board introduces conflicts and accountability problems as identified by Jensen (2000) Pejovitch (1990: 70), Sternberg (1997: 5) and Williamson (1985: 308). A board responsible to many constituencies becomes accountable to no one. These problems can be resolved with separate advisory stakeholder boards (Turnbull 1994, 1995a, 1997, 2000a,b,d,e,f, 2002a).

Another fundamental law of cybernetics is the related ‘Law of Requisite Variety’ which states "the variety of a regulator must equal that of the disturbances whose effect it is to negate" (Ashby 1968: 202). Another formulation by Beer (1995a: 41) is "that control can be obtained only if the variety of the controller (and in this case all parts of the controller) is at least as great as the variety of the situation to be controlled."

Beer describes this as Ashby's Law, which he observed is poorly understood. To overcome this problem, Beer (1995c: 84–96) provides several examples to communicate its meaning. Beer (1995b: 279) uses the football team metaphor to illustrate the law. The same number of players is required to provide an even chance for players in one team to compete with another. A team without sufficient players, (ie. requisite variety) becomes uncompetitive, and likewise, firms. This is why “complete centralised control is impossible in any complex system” (Mathews 1996: 41). It also provides one reason why “networks enjoy competitive advantages over traditional atomistic hierarchical firms” (Mathews 1996: 51).

In the words of Ashby (1968: 207) "Only variety can destroy [ie. control] variety". Another formulation of the law of requisite variety is that complexity is required to manage complexity. Non-trivial firms with a unitary board do not meet the test of possessing requisite variety in their information and control channels and so their competitive capabilities cannot match those with an appropriately designed compound board. Ashby’s law of requisite variety explains what Hock (1994: 7) refers to as the "second law of the universe: nothing can be made simpler without becoming more complex”. Persson, Roland, & Tabellini (1996) and Diermeier & Myerson (1999) have shown that an appropriate division of power, as is inherent in a compound board, can increase the welfare of all stakeholders.

Another insight of Asbhy is the impossibility of amplifying regulation. In discussing the capacity of any controller to regulate/manage variables, Ashby (1968: 268) states: "The Law of Requisite Variety, like the law of Conservation of Energy, absolutely prohibits any direct and simple amplification but it does not prohibit supplementation". “One man would not be able to directly load hundreds of heavy containers on to a ship but the Law of Conservation of Energy does not prohibit him from supplementing his energy by using a crane”.

Likewise, supplementation of regulation depends upon one regulator being used to regulate many others. One man could not regulate the temperature in a 100-room hotel as the weather changed during each day if he had to adjust the heaters/coolers in each room directly. However, if each room had a thermostat, which sensed changes in the air temperature of each room and made adjustments accordingly to its air conditioning system then one man could control the temperature of all rooms.

The law of requisite variety explains why it is impossible for governments to regulate the complexity of society without supplementation. However, as noted by Gore (1996) law makers are not aware[3] of this limitation and so keep on introducing more and more prescriptive laws in an effort to introduce greater regulation. The result is more red tape to frustrate business, more cost to government with problematical protection for consumers and investors for whom the laws are intended to protect.

Supplementation is essential because in the regulation of firms, one law/size does not fit all. It is by trying to protect the public for all firms in all situations that the law gets so complex. Instead of prescribing details/temperature for each firm/room, the law only needs to prescribe the processes by which each firm/room is regulated. Prescription is still needed but it is at a systematic level to ensure that supplementation is provided by each firm to introduce sufficient control elements for self-regulation.

It is by this process of supplementation that the architecture of the human brain with its hundred trillion (10^{15}) connections between its 100 million neurones (10^{8}) is created by the DNA code which contains less than one hundred thousand (10^{5}) genes (Kurzweil 1999: 203,

[3] Gore (1996) suggested that the reason for the lack of knowledge about efficient regulation in the USA in the “information age” was that only nine of the 535 members of Congress had any professional education in technology.

323). The DNA molecule contains the design instructions or "process information" (De Vany 1998) to not only build the human brain but all the rest of the body according to the embedded "structural information". This illustrate how the bytes required to build self-regulating complex structures can be reduced by many orders of magnitude by using massive additional information from the environment.

One strategy for achieving this end is illustrated by fractals that create complexity through repeatedly reproducing a simple pattern in slightly different ways with simple instructions. The recursive reproduction of similar patterns is described as self-similarity and this is illustrated in Section five. The economising of bytes by self-similarity and recursive patterns demonstrates the power of TBA to explain the structural patterns commonly found in biota.

Simon (1962) showed mathematically that the most effective way to build or manage complex systems is to use "sub assemblies" or "stable intermediate forms". He also described them as "nearly decomposable systems, in which the interaction among the sub-systems are weak, but not negligible". It is because the interactions between the are so weak it allows bytes to be prodigiously economised. It also allows complex systems to be constructed from "relatively independent sub-systems, each one of which can be designed with only minimal concern for its interaction with the others" (Simon 1962: 474). The "sub assemblies" as described by Simon meet the test of being a "Holon" as defined by Mathews (1996: 34). In describing holonic organisations, Mathews (1996: 34) uses a stronger definition than Koestler (1967), Hock (1994) or McHugh, Merli, & Wheeler (1995).

Mathews (1996: 40) states that the defining characteristics of a holon are: automony, system dependence and recursivity. As a result of these characteristics "no part of the system will possess complete information about any other part." This is consistent with evolution adopting an organisational architecture that minimises the transaction of bytes within, between and through a natural system.

Organisational holons are autonomous in the sense of being relatively self-sufficient that includes a "mechanism of continuous improvement, or learning" (Mathews 1996: 39). However, consistent with the Simon description of interactions among the sub-systems being weak, they are not expected to operate with absolute autonomy. "Holons are not expected to determine their tasks or themselves – these are given by the overall system design. But how they accomplish their tasks is up to them" (Mathews 1996: 39). Holon recursivity or concatenation, means that they follow a similar structure from one level to another to provide self-similarity and so a basis for systemic coherence. All these features are illustrated by the architecture of the MCC that also introduces a feature that this author calls "lateral" recursivity.

Mathews (1996: 40 –6) describes three orders of functionality, properties, dynamics and co-ordination that are found in all holonic systems. These are summarised in Table 2, <u>General characteristics of holonic sytems</u>.

The three orders of functionality refer to the (i) activity of a holon or *what* it does, (ii) *how* it does its tasks and (iii) *why* some processes are accomplished and not others. The three orders of properties being the (i) decentralisation and centralisation of *control*, (ii) *reliability* independent of other parts of the system, and (iii) *flexibility* to switch their function with minimal disturbance to the system as whole. The three dynamics being systemic (i) *responsiveness*, (ii) *learning* and (iii) self-renewal or *autopoiesis*. The three orders of co-ordination are being (i) *within* holons, (ii) *between* holons and (iii) in the total *system.*

Table 2, General characteristics of holonic systems

Order	**First**	**Second**	**Third**
Functions	What task	How to do it	Why to do it
Properties	Centralisation/decentralisation	Reliability	Flexibility
Dynamics	Responsiveness	Learning	Autopoiesis
Co-ordination	Within	Between	System

Mathews (1996: 47) states that

> The objective of organisational design is to create self-adjusting, self-renewing systems through a continuous process or organisational learning. To this end, mechanisms to ensure that self-renewal and learning take place need to be designed: they will not occur naturally, and indeed are blocked by most conventionally organisational architectures.

Without an understanding of holons and their characteristics it is difficult to explain how or why the complex organisational structure of the MCC could operate successfully, let alone be competitive on a sustainable basis. The TBA framework provides a basis to explain the cybernetic advantages of holons and a hierarchy of holons described as a Holarchy. The MCC is the most outstanding example of a holarchical organisation known to the author. It is used to illustrate holonic organisational architecture in the following section.

4 The cybernetic architecture of the Mondragón complex

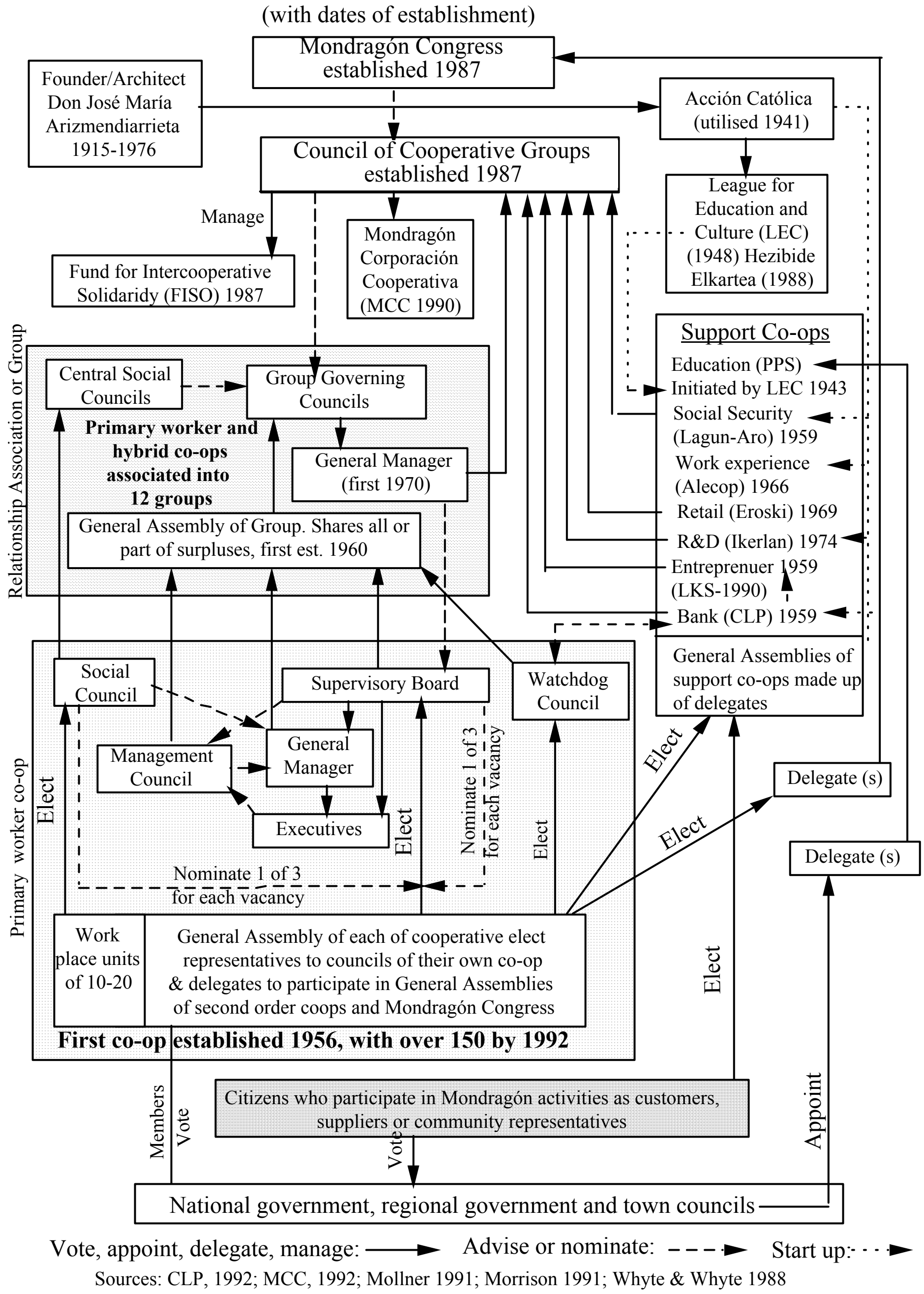
The information and control (cybernetic) structure of the MCC creates a formidably complex diagram as presented in Figure 1, MCC system with dates of establishing components. The author used the MCC for many years as part of a course in comparative corporate governance (Turnbull 1975) and for this purpose wrote a case study to explain the details of the MCC before he learnt about holons (Turnbull 1995b). Students as well as scholars found great difficulty in accepting that such a complex organisation could be sustainable let alone competitive. The general reaction was to immediately reject the MCC as providing any lessons for designing an efficient and effective business. Cybernetic arguments based on obtaining requisite variety of decision making, information and control channels were not compelling for readers who accepted simple command and control hierarchies as the natural order of efficient and competitive organisations. However, throughout the universe, holarchies represent the natural order as shown below.

Figure 2, Control network of the MCC was constructed for Turnbull (1995b) as a way to present the complexity of the MCC organisational architecture in a simpler way than Figure 1 before identifying its Holonic structure. Recognition of its holonic structure not only provides a way to simplify the complexity of the MCC further but more importantly explain it. As noted by Hock, “Nothing can be made simpler without becoming more complex”. A point well illustrated by the complexity of the MCC, which simplifies the transaction of bytes for its individual members by increasing the complexity of the system.

Simplification depends upon decomposing decision making labour in multiple centres with associated multiplicity in information and control channels such as indicated in Figure 1.

TBA provides a framework to explain the degree of decomposing decision making labour as presented in Turnbull (2000f, 2002b).

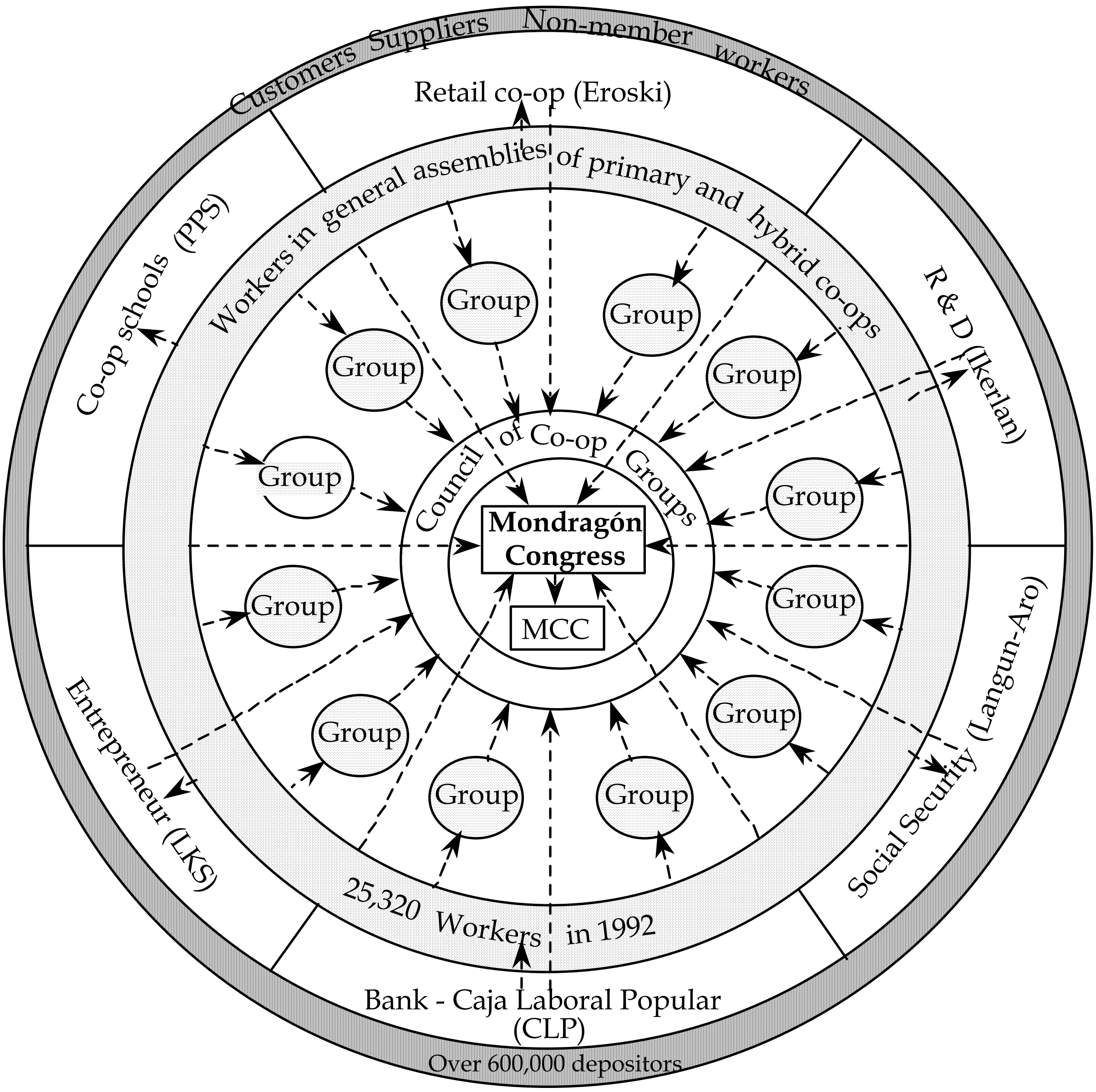
Figure 1, MCC system with dates of establishing components



The large shaded rectangle area at the bottom of Figure 1 outlines the cybernetic architecture of a primary cooperative. The governance of primary cooperatives has five constitutionally separated decision-making centres. These are the General Assembly, Work Groups, Social Council, Watchdog Council and Supervisory Board, Management Council with the last four being components of its compound board. Details are provided in Turnbull (1995a).

When a firm grows to employee more than around 500 people part of its operations are spun off into a separate firm that becomes a supplier or customer of the progenitor business. In this way the MCC grows organically like an amoeba. It also keeps the size of firms within the "critical threshold beyond which social cohesion can be maintained only if there is an appropriate number of authoritarian officials" (Dunbar, 1993: 687). Another neurological limit identified by evolutionary biologist, Dunbar (1993: 685) was that the human neocortex restricts the maximum number of people an individual can establish social bonds and trust with to around 150.

Figure 2, Control network of MCC



More than 150 primary worker and hybrid co-ops are associated into 12 groups or relationship associations

Total 1992: Assets US$6.3 bn.; Sales US$3.0 bn.; Exports US$380m.

Based on information in: Whyte & Whyte (1988); Morrison (1991); MCC (1992)

The newly created or "offspring" firm is imprinted with a similar cybernetic architecture as the progenitor firm by the MCC bank as a condition for financing its formation. The imprinting is achieved through a contract of Association with the bank that also makes the new firm a part owner of the Bank (Turnbull 1995b: Appendix). The Contract of Association acts as the DNA of the MCC determining the constitutional architecture of member firms.

Geographic or activity associated firms form a "Relationship Group" that in turn adopts a cybernetic architecture that follows the pattern of its constituent firms as shown in the upper shaded rectangle in Figure 1 and the circles spread around the unshaded annulus of Figure 2. It is in this way that the MCC forms concatenated or nested networks of network firms. All components of the MCC are coordinated through a third tier of control centres shown in the highest shaded rectangle of Figure 1 and in the central annulus and rectangles of Figure 2.

An analysis of the MCC from a holonic perspective is presented in Table 3, Holon typology of Mondragón. Table 3 simplifies even further the presentation of the complex inter-related information and control system of the MCC shown in Figure 1, by identifying its common recursive vertical and lateral patterns. It is through such self-similarity that nature minimises the bytes required to create complexity through fractals. Simple instructions described as "state description" (Simon 1962: 479) or 'rule forms' (Long, & Denning 1995) can create far greater complexity requiring massively more bytes to describe than the building instructions that create them, as discussed in the previous Section.

Table 3, Holon typology of Mondragón

Concatenated holons		**Integrity (support) holons (Note a)**	
Productive	Intra-support vertical recursivity	Supports all productive holons in the system	Lateral recursivity
25,320 Individuals (MCC 1992)	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
150 Firms (MCC 1992)	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' (MCC 1992)	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	

Note (a) Integrity Holons would appear to be what Mathews (1996: 46) refers to as "professional support".

The MCC, its groups, support cooperatives and primary cooperatives meets the definition of Mathew (1996a: 34) of being a holon as each is "endowed with its own processing ability, its own autonomy, its own 'mind' or intelligence". To obtain autonomy, firms need to be self-governing and a condition for self-governance is the existence of an appropriately designed compound board (Turnbull 2001f: Table 5). This condition is met at all levels for all components of the MCC.

Each primary cooperative of the MCC is made up of almost self-governing "sub assemblies", "stable intermediate forms" or "nearly decomposable systems, in which the interactions among the sub-systems are weak, but not negligible" in the language of Simon (1962). Beer (1985: 117) would refer to each cooperative as a “viable system”. This is proved by primary cooperatives being fee to leave the MCC if they wish and some have. Hock would describe the components of the MCC as “Chaords”. “By Chaord, I mean any self-organizing, adaptive, non-linear, complex community or system, whether physical, biological or social, the behaviour of which exhibits characteristics of both order and chaos. Or, more simply stated a Chaord is any chaotically ordered complex” (Hock 1994: 1)

Hock (1994: 7) explained that VISA International "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". In this way the components of VISA follow some of the criteria for being a Holon that provides a way to achieve a prodigious reduction in the transaction of bytes between them.

The component firms of a Japanese Keiretsu have stronger holonic architecture. The information and control networks created by a Japanese Keiretsu provided a simpler example to the MCC of multiple information feedback and feed forward channels to cross check the integrity of decision making information and plan for the future as discussed in Turnbull (1997, 2000d,e, 2001a, 2002a,c).

The MCC also illustrates a hierarchy of holons or holarchy, that Simon (1962) described as “ordered hierarchical” forms. Other writers described the vertical modular structure as “concatenated”, or “encapsulation” (Matthews 1996: 39).

So well does the Holonic architecture of the MCC replicate the processes in nature of constructing complexity efficiently that it appears to be an extension of nature as indicated in Table 4, Holarchy: Hierarchy of holons. The Table outlines the concept of “holism” developed by Smuts (1926) who noted how emergent properties developed in the whole (hol) that was different from those of its constituent parts. The MCC answers the question raised by Bernus and Nemes (1999: 193) who asked “ If it was possible to design models of organisational entities (cells, teams, workshops, departments, etc.) so that all of these would have the same control protocol (including negotiation and commitment) then organisational design would be simpler and more flexible”.

The rows in Table 4 have been divided into three arbitrary “levels” of first, second and third, which have no intrinsic significance but allows each row to be described as a “discipline” or a subject such as physics or chemistry. It will be noted that the holonic components listed as the “third level” becomes the Holonic components of the next “first level”. Rows one to seven are linked in this sequential manner to describe nature. The remaining eight rows describes the structures created by humans and do not maintain linked hierarchies between rows except for rows 10 and 11 which describes the MCC.

The Holarchy shown in row 11 of Table 4 is shown in the first vertical column of Table 3 with the third level of row 5 (individuals) of Table 4 included as the top entry of Table 3. The holarchies illustrated in Table 4 shows how the MCC social system represents a natural progression of the structure of nature. This architecture evolved in nature to provide competitive advantages such as adaptability with robustness in control, reliability, and so sustainability.

Table 4, Holarchy: Hierarchy of holons

In nature (rows 1–7), society* (rows 8–13) and engineering (rows 14 and 15)
*Contains components that typically do not meet the test of being a Holon

	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	Biota/Individuals
6	Environment	Biota	Ecological systems	Gaia (Earth)
7	Astronomy	Earth	Solar system	Galaxy
8	Sociology	Individuals	Families	Communities
9	Organisations	Autonomous cells/divisions*	Firms*	Keiretsu /groups
10	Mondragón Co-op	Individuals	Social council, etc.	General assembly/Co-op
11	Mondragón system (MCC)	Co-operative	Cooperative groups	Mondragón Corporación Cooperativa (MCC)
12	VISA Card	Member Bank*	Regional/functional Unit	VISA International
13	Government	Local government*	Regions/States*	Nations*
14	Engineering	Components	Sub-assemblies	Machine
15	Software design	Sub-routines	Routines	Object-orientated programs

One fundamental characteristic found in nature and the MCC holarchies is the “principle of subsidiary function”. The principle of subsidiary function is analogous to the need to limit the span of command of an executive. The objective being to minimise the need for individuals to transact bytes which can create information overload and bounded rationality. One form of this principle was enunciated by Schumacher (1975: 203) who stated, “that no higher order association should undertake any function, which can be undertaken at a lower level”. The principle was also advocated in the Encyclical Letter of Pope Pius XI (1931:40) which probably influenced the thinking of the Jesuit Priest who designed the architecture of the MCC. His initiative and that of Hock to custom design organisational architecture provides a role model for CEOs and points out the need for management schools to develop organisational design courses. TBA provides a way to develop a science of organisations based on the natural sciences.

The contrary properties found in holons reflect another ubiquitous design feature found in nature that was given the name of “tensegrity” by Fuller (1975). He created the word by contracting the words *tensional integrity*, because it refers to structures that use tension and compression in its components. Geodesic domes invented by Buckminster Fuller use this design principle to obtain the greatest strength for the least weight. This design strategy is now commonly used in engineering structures. For example, concrete is good in compression but not in tension. Steel rods can withstand tension but not great compression so the two are commonly used together to create reinforced concrete. Tensegrity has been popularised by the sculptures of Kenneth Snelson[4] who was inspired by attending a lecture by Buckminster Fuller in 1948. A mathematic basis has now been developed to design tensegrity structures (Connelly, R. & Back A. 1998).

Tensegrity is used in biological structures as described by Ingber (1988: 32). He states that: "Organic structures – from simple carbon compounds to complex cells and tissues" utilise this principle as it offers "a maximum amount strength for a given amount of building material". The human body illustrates the design feature of tensegrity. Neither the human skeleton, which is designed to withstand compression forces, nor muscles which operate as a tension component, can create a stable, strong or adaptable structure on their own. But in combination they create not only a stable structure, but also one that can maintain stability in very many configurations. TBA posits that social stability through self-regulation is likewise facilitated in this way.

Social animals like humans possess many contrary behavioural traits like being competitive and cooperative, trusting and suspicious, selfish and altruistic, aggressive and timid and so on. Such contrary and changing behaviour in social animals is the result of evolutionary needs to facilitate the survival of the specie. However, command and control hierarchies depend upon people being subservient to obey orders and suppress contrary behaviour to be a good team player. Likewise the use of markets to govern activities depends upon people being self-interested and competitive. Markets would not be "efficient" in economic terms if people became altruistic and cooperative! Neither markets nor hierarchies were used by Australian Aboriginals to govern their activities for longer than any other society (Turnbull 1978: 52).

Holonic networks, with a division of power, checks and balances and interdependencies provide an organisational architecture in which people can express contrary and inconsistent traits. Indeed, it would seem that the stability and effectiveness of holonic organisational architecture is very much dependent upon negative and positive social relationships to provide dynamic balance to assure the integrity of their self-governance as autonomous organisational units. Paraphrasing the words of Ingber and applying TBA leads to the hypothesis that social tensegrity provides "a maximum amount of control (strength) for a given amount of bytes (building material)".

Like Simon and Hock, Ingber did not use the word "Holon" to describe a "component" when explaining the role of tensegrity in biological structures. Ingber (1998: 30) stated:

> This phenomenon, in which components join together to form larger, stable structures having new properties that could not have been predicted form the characteristics of their individual parts, is known as self-assembly. It is observed at many scales in nature. In the human body for example, large molecules self-assemble into cellular components known as organelles, which self-assemble into cells, which self-assemble into tissues, which self-assemble into organs. The result is a body organized hierarchically as tiers of systems within systems.

While Ingber was describing the role of tensegrity in creating self-assembled structures, it is clear than he is also describing holons and a holarchy although he did not name them as such.

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[4] Pictures of the work of artist Kenneth Snelson can be viewed at http://www.teleport.com/~pdx4d/snelson.html. Mathematically designed structures can be viewed at http://www.sigmaxi.org/amsci/articles/98articles/Connelly.html

Just as the physical stability of simple carbon compounds, complex cells, tissues and the human body is established by combining both compression and tension components one can hypothesise that sustainable stability of social organisations depends upon providing opportunities for competition and cooperation or selfishness and selflessness together. Like ying and yang, too much of either characteristic can be dysfunctional; a balance of both is required. The phrase "sustainable stability" is used to differentiate organisations, which maintain their stability or viability, from special attributes of key personalities who happen to be influential in their operations at a particular time. The distribution of power in a MCC create a situation in which competitive and cooperative "forces are distributed and balanced within the structure" as described by Ingber (1998: 31).

An inherent feature of social Holonic architecture is its ability to accommodate contrary properties as referred to above by Matthews (1996: 41–4) and Hock (1994: 7). It also provides a basis for providing a prodigious reduction in data transmission and in data complexity as described by Mathews (1996: 30). In social organisations social tensegrity can also make a contribution in this regard as it provides a basis to maximising the ability of an organisational unit to achieve self-regulation and so self-governance while minimising the transaction of bytes. The establishment of almost self-governing organisational units is itself a strategy for minimising the transaction of bytes.

5 Comparison of TBA and Transaction Cost Economics (TCE) paradigms

TBA provides a way to investigate how communications between people affects the performance of any type of organisation. TBA also shows how cybernetic principles provide a basis for identifying "organisational advantage" which Nahapiet & Ghoshal (1998: 261) say is "as yet inadequately understood." The TBA framework is universal. It can be applied independently of organisational form, structure, purpose or social context. By allowing organisational analysis to be grounded in the physiological and neurological characteristics of people and the laws of cybernetics, TBA provides a framework for evaluating or designing institutions.

As information can alter the behaviour of people, individuals become both a dependent and independent variable. The variability of people and the variability in the ways in which people transact bytes become the focus of concern. Because people have limited ability to receive, store, retrieve, analyse and transmit information, the effectiveness of firms becomes dependent upon keeping the capacity of people to transact bytes within their capabilities. The information and control architecture of firms also needs to compensate for any variability in human capabilities and motivations. This makes the effectiveness of firms dependent upon how well their information and control architecture allows individuals to operate within their cybernetic limits and compensate for human variability.

While much of TBA is grounded in the work of Williamson, TBA creates a different framework of analysis. To use the words of Kuhn (1970: 80) who was describing a "paradigm shift", 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". The TCE framework is based on "costs" while the TBA framework is based on "bytes". The differences between the TCE and TBA frameworks are outlined in Table 5, '<u>Comparison of TCE and TBA paradigms</u>'.

TBA extends the boundaries of analysis of TCE as shown in Table 5. Just as Newton's "Laws" of motion are relevant to only limited situations covered by Relativity Theory, so is TCE relevant to only limited situations covered by TBA.

Another limitation of TCE, noted in the first row of Table 5, is that it assumes firms are not labour-managed. Williamson (1985: 265) states that he, "is mainly preoccupied with assessing capitalist modes of organisation". He acknowledges the existence of Mondragón enterprises but dismisses them as an "experiment" but notes that labour managed firms require "further study". As indicated in row four of Table 5, the relationship of people is master/servant or competitive whereas with TBA the relationship can be competitive and/or cooperative consistent with the observation of Wearing (1973).

However, even with capitalist firms, Barney & Ouchi (1986: 8) note that there are "theoretical and empirical anomalies". They go on to say that, "...the search is on for a more general framework, a framework that will include the insights of the traditional theory, but will place those insights in a context that allows the theorist to explain a wider diversity of economic and, particularly, organisational phenomena". They identified the need for "a new paradigm for understanding and studying organizations". TBA is presented as such a framework grounded in the physiological limitations of people to transact bytes and the science of cybernetics.

Table 5, Comparison of TCE and TBA paradigms

	Framework of analysis→	**TCE (Coase/Williamson)**	**TBA (Developed by the Author)**
1	**Type of social institution**	For-profit firms not labour managed	Any social organisation, including any type of firm
2	**Subjects of analysis**	Transactions and their costs	People and the quanta (bytes) of information they process
3	**Unit of analysis**	Cost	Bytes
4	**Relationship of people**	Master/servant or competitive	Any eg. Family, master/servant, cooperative, competitive, associative, etc.
5	**People behaviour**	Independent variable. Constant self-interest, opportunism, competitiveness, etc.	Dependent variable. Changeable and contrary such as self-interested/altruistic, opportunistic/selfless, competitive/cooperative, etc.
6	**Objectives**	Economising costs	Anything. (For firms, economising the transaction of bytes by people while compensating for errors with redundancy)
7	**Basis for objective**	Normative to reduce costs	Physiological limits in transacting bytes
8	**Modes of governance**	Markets, hierarchies and hybrids of both	Combination of clans/communities, associations, hierarchies or markets
9	**Communication and control through:**	Markets and hierarchies	Related mixes of senses, semiotics, words and numbers
10	**Firms of two or more people exist because:**	Markets fail to provide information economically	Complex tasks can be carried out with individuals transacting fewer bytes and/or need to exceed other limits of individuals.

A fundamental difference between the two frameworks is that the subject of analysis of TCE is the social construct of “transaction cost” while TBA is founded on instrumental considerations based on the physical limitations of people to handle bytes of information as shown in the second row of Table 5.

It was Commons (1934: 4–8) who suggested, "that the transaction is properly regarded as the basic numaire of analysis”. This suggestion was made some 14 years before Wiener (1948) identified the science of cybernetics. In 1934, it was not practical to consider bytes of information rather than costs as criteria for governing transactions as presented in row three. In any event the discipline of economics is based on the social constructs of costs and prices, which are assumed, or asserted to provide the basis for allocating resources – an assumption questioned by Dallas (1988: 37). Although bytes can be a sub-set of costs and prices, they were, and may still be, considered to be outside the discipline of economics. But as shown by Klaes (2000) the description of a transaction and its cost has changed over the years with little agreement between the various writers.

TCE is based on firms being an “authority system”, (row four of Table 5) as assumed by Coase (1937) and that they exist because they reduce the cost of governing transactions through the market. TBA extends the type of relationships between people to any of the four types shown in row eight of Table 5 as identified by Hollingsworth & Lindberg, (1985: 221–2). This extension allows the relationship of people on boards to be analysed. The TBA framework also provides a basis for developing a more comprehensive, compelling and relevant reasons why firms exist as indicated in row ten of Table 5 (Turnbull 2001b).

The subject of analysis (shown in row two of Table 5) creates different objectives in row six with TCE based on economising costs, while the concern of TBA in firms is to keep people operating within their information processing limits while compensating for errors. TCE assumes that people are opportunist and self-interested, while with TBA people may be altruistic, self-interested or possess any other type of behaviour shown in row five of Table 5. As noted above, belief that costs should be minimised is a normative view of TCE, which is questioned by scholars such as Alchian & Demsetz (1972) and Dallas (1988) because of the difficulty of senior managers in non-trivial firms to possess the information or will to reduce costs. This view is presented in row seven of Table 5 which notes that the reason for TBA objectives are grounded in the physiological limitations of people to transact bytes.

TBA recognises that transactions can be governed through four rather than the two methods recognised by TCE in row eight of Table 5. Communication and control in the Coasian/Williamson framework is through "the limited institutional repertory" of markets and/or hierarchies rather than the four modes of governance as identified by Hollingsworth & Lindberg, (1985: 221–2) in row eight. Each governance mode has a related mix of communication channels listed in row nine. The mix of channels used in each mode of governance is described in Turnbull (2002b). However, some of these channels are invisible to scholars who do not recognise that there are four modes of governance rather than two or three.

In discussing the theory of the firm 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..." and for the need for finding a new paradigm, as proposed by Barney & Ouchi (1986). Winter (1991: 193) went on to observe, "In the past half-century, it has been clearly demonstrated that the economy is much better at changing itself than economists are at changing their minds".

Another problem for organisational theorists is to explain the current trend for vertically integrated firms to relinquish direct control of their suppliers and move towards looser forms of collaboration or even networks. In some dynamic industries like fashion textiles, movie making and knowledge intensive high tech electronics and biological firms, network organisations dominate. Participants may change between collaboration and/or competing with each other. This has led theorists like Zingales (2000) to state that existing theories "seem to be quite ineffective in helping us cope with the new types of firms that are emerging". He raised four questions that any new theory must answer. Turnbull (2001b) showed that TBA could provide answers to each question as well as grounding corporate governance in system science (Turnbull 2002c).

Williamson (1991: 11) states: "...Winter like Demsetz, also emphasises the importance of knowledge acquisition and its utilisation 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?" This paper presents "bytes" as the answer to this question and that they provide the foundation for a "science of organisation" grounded in cybernetics.

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