

Unfolding Systems Boundary: Evolution and Implication

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ABSTRACT: *The characteristics of systems boundary are unfolded by tracing the conceptual evolution of boundary in diverse and multiple disciplines, including systems approaches, organisational studies, chaos theory, and Chinese Taoism. Some key ideas revealed include difference as the origin of boundary, the primary (non-supplementary) role of boundary, buffering and spanning as boundary strategies, transforming and displacing boundary for network strengthening, the boundary as a chaotic state, and the dynamic, paradoxical, dialectical and recursive natures of the activities at the boundary, and positivist, interpretive and critical implications of the boundary in systems theories.*

Key Words: systems boundary, boundary thinking, systems thinking, boundary, difference, network

INTRODUCTION


Boundary is an enigmatic and intricate entity. It can be as simple as a line or a border or a divider between units or functions or identities. It can also be thought of as a limit or an edge or a state between quanta of knowledge or people or consciousness.

Various conceptualisations of boundary have been advanced, including boundary as a cross-system interface and frontier across which the enclosed system acquires resources crucial for its survival (von Bertalanffy (1950), Katz and Kahn (1966), Beer (1981), and Scott (1987)), as the closure of a purposeful system (Forrester (1968) and Churchman (1968)), and as a being itself and an interlocking intermediary for networking (Bateson (1972), Derrida (1982), and Cooper (1990)). The intrinsic intent of systems boundary is neutral, or dimension-less (Bateson (1972), Cooper (1990)). But the extrinsic meaning of systems boundary can be of a positivist, interpretive, critical or dialectical nature (Churchman (1968), Ackoff (1981), Checkland (1981), Ulrich (1994 [1983])). We also find some implications of boundary concept from Taoism, Chaos theory and postmodernism.

In the next several sections, systems boundary in these various disciplines is introduced in a time order, and then the implications reveal from the unfolding process are summarized.

Boundary in Taoism

Taoism, which originated at about 500 BC in China, discusses the dynamic interaction at the boundary between Yin and Yang. "Tao produced Oneness. Oneness produced duality. Duality evolved into trinity, and trinity evolved into the ten thousand things. The ten thousand things support the yin and embrace the yang. It is on the blending of the breaths (of yin and yang) that their harmony depends." (Lao-Tzu, ch 42, quoted by Fung (1952), p178). Tao, from the empty state, generates existence, Oneness, which represents the initially "chaotic" state of the universe.

Taoism envisages the entire universe, both natural and social, as being in a state of dynamic balance between the two archetypal poles —Yin and Yang. The famous Tai-Chi symbol "" is a continuous cyclic movement of Yin and Yang in the rotational symmetric arrangement. The direction of change is dynamic, subject to the relative strength of, and to the interaction with, each one. Whenever one extreme is about to be reached, reversal will take place. By doing so, Taoism with its unique format of duality (Yin and Yang) endows movement at the boundary with a dynamic and dialectic nature. Also, there is a recursive implication in the movement. Yin and Yang are embedded in Tai-Chi and their interactions enclose the next level of Tai-Chi.

Boundary in open systems

Boundaries and boundary activities have received attention from organisation scientists since the late 1950s when an open system perspective on organisations began to proliferate. In an open system, the boundary should remain permeable and thus exchange energy and information with its environment in order to prevent the system's entropy from increasing (von Bertalanffy, 1950).

System boundaries refer to "the types of barrier conditions between the system and its environment which make for degrees of system openness". (Katz and Kahn, 1966, p60). Boundaries are the demarcation lines or regions for the degree of openness, across which imports into the system occur. A Boundary, on one side, constitutes a barrier for many types of interaction between the people inside and outside; on the other side, it includes some facilitators for particular types of transactions necessary for organisational functioning. "By passing the boundary and becoming a functioning member of the organisation, the person takes on some of the coding system of the organisation, since he accepts some of its norms and values, absorbs some of its subculture,

and develops shared expectations and values with other members." (p228) The permeability of the boundary operates in organizations.

Boundary in System Dynamics

Forrester (1968) defines systems boundary as a system closure which encloses a system of interest, a system with purpose. Given a purpose, he states, a boundary should include the smallest possible number of components that are linked together with a quantified causality. The boundary of a system is the imaginary line separating what is inside from what is outside for *modelling* purposes. Richardson and Pugh (1981) explain, "if one insists on the view that everything is connected to everything else, one is paralysed, prevented from ever concluding an analysis that always stretches on to yet more variables and effects." (p42)

"Without a purpose, it is impossible to define the systems boundary". "An essential basis for identifying and organising a system structure is to have a sharply and properly defined purpose." (Forrester, 1968, quoted by Richardson and Pugh, 1981, p43) From the system dynamics perspective, one of the first criteria for a correctly drawn systems boundary is the closing of feedback loops in the system. Forrester explained this by using a causal loop diagram to show the relationships, connections and dependencies among four sub-systems — production capacity, sales effectiveness, order to delivery process, and sales force. The objective is to identify and explain the system which can cause stagnation of sales growth even in the presence of an unlimited market.

The recently developed "qualitative" system dynamics (Senge, 1990) demonstrates mental models in a dynamic and dialectical format in which system archetypes are designed with the intent of focusing on the dynamic interaction at the joint point of reinforcing loop and balancing loop, virtuous circle and vicious circle. Managing tensions and paradoxes at the joint becomes paramount in any sustainable improvement. The purpose of the whole is not the purpose of either circles/loop, but is the dynamic movement of them all. Thus, the systems boundary of the whole encloses all elements in the paradoxical movement.

Boundary of a Critical and Dialectical Nature

Churchman (1968, 1979) claims the social construct of boundary is of a critical nature. The boundaries are not given by the structure of reality, but are constructs that define the limits of the knowledge that is to be taken as pertinent. When it comes to human systems, pushing out the boundaries of analysis may also involve pushing out the boundaries of who may legitimately be considered a decision maker. Thus, the business of setting boundaries defines both the knowledge to be considered pertinent and the people who generate that knowledge and who also have a stake in the results of any attempts to improve the system. The boundary of analysis is critical. What is to be included in, or excluded from, the analysis is a vital consideration: what may appear to be improvement within a narrowly defined boundary may not be improvement at all if the boundaries are pushed out. Boundary setting determines who should be involved in the decision-making process.

Churchman (1968) argues "...the systems approach means looking at each component part in terms of the role it plays in the larger system; but there appears to be a deep paradox in this rather obvious prescription of rationality. The paradox is of the 'Who shall decide?' variety. Who shall decide how to look at each component, when 'looking at' means 'conducting extensive research?'" "Paradox is not the end but the beginning of the formulation of an idea." (p103)

The pitfall of the systems approach is that, in its endlessly holistic seeking process, the systems boundary may not be definable, and thus the system may lose its own identity. To answer this critique, Churchman argues that the systems boundary can only be determined and again unfolded in a dialectical process through the endless debate between the systems approach and its enemies. Churchman always refers to the systems approach as ideal planning, and its enemies as objective planning. The differences between these two have been presented "in a dialectical manner". Churchman (1979) quotes Kant to explain such a dialectical presence: if there are two contradictory propositions — the world is infinite in quantity, and the world is finite in quantity, then we can assume the world is a thing in itself, in the complete series of paradoxical phenomena.

Ulrich (1994[1983]) develops Churchman's boundary judgement in social planning. System is regarded as the unknown totality of relevant conditions behind the phenomenal reality that can become an object of our maps and designs. Ulrich makes a comparison between Kant's totality concept and Churchman's systems concept, "like the concept of totality, the systems concept refers to the critical idea of a whole relevant conditions, a whole that we cannot possibly *know*, although we can and must nevertheless *think* it. But unlike the concept of totality, with its implication of an unconditioned, transcendent reality (the totality of conditions is always itself unconditioned), the systems concept has the advantage of reminding us of the relative character of every system of which we can meaningfully speak." (p227) What belongs to the system is a matter of the inquirer's choice of the conceptual boundary that separates the concerned system from its context.

For the purpose of boundary setting and systems mapping, Ulrich raised a list of 12 questions that can be used heuristically to define what the system currently is and what it ought to be. The purpose is to find a means of revealing the boundary judgements being made, and a means of postulating alternative boundary judgements.

Such boundary judgements are crucial in social systems mapping and designing. Also, boundary judgements are not absolutely a priori, that is, they must be made before the relevant section of the real world can be mapped. "Boundary judgements are not a posteriori (they cannot be derived from experience), and they are *not* analytic (their negation are not self-contradictory)" (p227), instead, they are "synthetic a priori judgements" (p228). "The normative content of the answer to the question of what the boundaries should be cannot be justified by referring to the data availability, to presently accepted boundaries, or to the success of instrumental action. The normative content can be justified only through the voluntary consent of all those who might be affected by the consequences." (p226-227)

Boundary Originated from Difference

Boundary separates one thing from another, and thus makes a difference, in some sense, be it physical or mental. According to Bateson (1972), there are an infinite number of differences around and within an object, and between the object and its environment. Information includes a limited number of differences that make difference. When we deal with information, our minds receive, record, recreate and transform differences. We do not experience things in themselves in their full, but as "transforms of differences" (p316) of them.

Cooper (1990) explains Bateson's idea, "the world of form and communication deals only in differences". "It is the continual deferral of presence that characterises 'system' as a seriality of differences..." "In fact, the mind too is difference." "difference, or information, cannot be located or placed because it is dimensionless." (p175)

Derrida (1982) develops the concept of difference through his unique postmodern reasoning. He uses a notion "*différance*" which combines "to differ" in space and "to defer" in time, "...to differ as discernibility, distinction, separation, diastem, *spacing*; and to defer as detour, relay, reserve, *temporisation*". (p18) "The first consequence to be drawn from this is that signified concept is never present in and of itself, in a sufficient presence that would refer only to itself. Essentially and lawfully, every concept is inscribed in a chain or in a system within which it refers to other, to other concepts, by means of the systematic play of differences. Such a play, *différance*, is no longer simply a concept, but rather the possibility of conceptuality, of a conceptual process and system in general. For the same reason, *différance*, which is not a concept, is not simply a word, that is, what is generally represented as the calm, present, and self-referential unity of concept and phonic material." (p11)

Cooper (1990) comments on Derrida's idea, "since *différance* is ever-active play, it cannot be located in any particular place, which is Derrida's way of characterising Bateson's idea of information (differences) as a zero from which is not locatable. It may be thought that *différance* can at least be approached but it moves away before being fully caught." "The differences of *différance* have neither a locatable presence nor a specifiable cause." "It follows that a conception of 'social system' in these terms must dispense with the perception of an interactional structure that is fully given to us in the present; social structure can only become 'present' to us through *différance* which, though it constitutes presence, can never be present." (p179) "*Différance* is a continuous centre that continually divided itself; *différance* is divided presence." (p179)

Systems boundary can be considered as a typical representation of *différance*. By dividing itself in the endless unfolding process, the boundary itself becomes a paradoxical presence.

Boundary in Viable Systems Model

In Beer's (1981) Viable Systems Model (VSM), there are some crucial boundaries for maintaining the balance between autonomy and control, for instance, the one between System 1 and System 3. The interactions between System 1 and its local environment and between System 4 and its "environments of decision" (p181) are crucial for adapting to environmental changes. All "indications of relevance" about the total environment of the organism are collected by System 4, and then switched into System 5.

Moreover, we see recursive phenomenon in VSM. System 1 itself is a viable system, and is actually the next recursion level of the current system. The boundaries between various sub-systems, and between the system and the environment, also become recursive. This nature is analogous to that in the Tai-Chi of Taoism.

Boundary in Soft Systems Methodology

Checkland (1981) claims, in a formal system model (a purposeful and generalised model of any human activity system), the boundary is "the area within which the decision-taking process of the system has power to make things happen, or prevent them from happening", and "more generally, a boundary is a distinction made by an observer which marks the difference between an entity he takes to be a system and its environment." (p312)

In Soft Systems Methodology (SSM), there is a crucial and conceptual interface dividing the systems thinking world and the real world. The expression of the problem situation (stage 2 of SSM) and the comparison against the perceived reality (stage 5 of SSM) are within the interface where an accommodation can be formed and a consensus reached finally through recurrent debates.

Checkland claims, "in 'soft' systems — which include most human activity systems considered at a level higher than that of physical operations — there will always be many possible versions of the 'system to be engineered and improved'" and "system boundaries and objectives may well be impossible to define" (p165).

Checkland agrees with Vickers by arguing that the purpose of a social system may not be goal-seeking, but could be better described as "relationship maintaining". In SSM, the initial expression of the problem is about building the "richest possible picture" (p165) that enables multiple and relevant view points to be revealed in later stages.

The purpose of comparison in stage 5 is to bring multiple conceptual models into the real world, to set them against the perceptions of what exists there, and to generate a debate with concerned people in the problem situation which is expressed in stage 2. Therefore, stage 2 and stage 5 in SSM are typical boundary activities that are somehow subjective and difficult to be guided in the practice of SSM. Whether the gap between the systemic model and the realistic complexity is "bridgeable" or "unbridgeable" (p312) is crucial.

Boundary Strategies

Scott (1987) summaries two boundary strategies: Buffering and Spanning. Boundary buffering is about the demarcational and perimetric views of boundaries and emphases that boundaries can serve to seal off or to cushion the technical core of an organisation from disturbances in the environment. Relevant tactics include technology coding, stockpiling, levelling or smoothing variability in inputs and outputs, forecasting variations and uncertainty, and scale adjusting. This buffering function of boundaries stresses the need to close the system off from environmental changes in order to enhance the possibility of rational action within the system.

The perspective of boundaries as frontiers of transactions and as interfaces between a system and its environment represent the foundations for spanning as a key boundary activity. Examples of spanning activities include bargaining and negotiation, contracting and co-operating, and building alliances and coalitions. "Bridging strategies may be viewed as a response to increasing organisational interdependence. Interdependence can occur when two or more organisations that are differentiated from one another exchange resources." (p186)

Boundary in Chaos Theory

When observing the famous Mandelbrot Set used as a typical example in chaos theory, we find there is no clear-cut distinction between the system and the environment. Instability and stability are intertwined and the projected boundary behaviour is inherently unpredictable. At the fractal border between the bounded and the unbounded sets, there is a "third" state, a paradoxical combination of both the bounded and the unbounded sets, a chaos with self-similarity, a bounded instability.

On this phenomenon, Stacey (1993) makes some very thoughtful comments, "Their variety and beauty are such that we can describe such mathematical systems as ones that are continuously creative. If a system is not conscious and yet produces an endless stream of new and beautiful forms, it might be argued that it is just as creative as a conscious system doing the same thing."(p215) The creativity displayed in the continuously dividing process at the edge of the system can be the impetus for system renewal and business reengineering.

A further implication of identifying organization as bounded and environment as unbounded is that we have to look at a long period of time to allow all the interactions to unfold in order to see completely the chaotic nature of the border between the organization and its environment. Moreover, the specific boundary conditions are vital for generating specific behaviours. A tiny change in the environment or in the initial set-up can be amplified by the system's feedback mechanism, and so dramatically change the system behaviour in the boundary area. In this area, there may be abrupt transitions from chaos into some new complex order, or from complex order into chaos. However, the system does not respond to all of the possible disturbances. There is therefore some mechanism of selection at work; this mechanism is as yet not at all well understood.

The Primary Role of Boundary: from System Closure to System Transforming

Cooper (1990) links the concept of boundary with Bateson's "difference" and Derrida's "*différance*". He claims that the universe is constituted by many divisions such as, man-woman, teacher-student, night-day. "There are two ways of interpreting such binarity: (a) by placing the emphasis on the two separate terms, or (b) by focusing on the division boundary between the terms." "To understand (b) requires that the division between terms be conceived no longer just as a separation but also as a structure that joins terms together, i.e. division both separates and joins." (p173) The boundary is now conceived not as a static concept, but as an active process of differentiation which serves system and environment equally. "...to recognise the primary (i.e. non-supplementary) role of boundary as the source of paradox and contradiction in social life and to relegate "system" to the secondary and supplementary role. "system" thus loses its position of centrality in the theoretical analysis and becomes an adjunct to 'boundary' and 'difference' which are then seen as the true problematics of social action." (p171) Cooper (1992) argues that the role of boundary as systems closure should be denied and defied since the system itself is in "an active process of displacement or transformation" (p262). Instead, the boundary should be regarded as an intermediary for system transforming and interlocking.

Boundaryless?

"Our dream for the 1990's", Welch (1990) claimed, "is a boundaryless company ...where we knock down the walls that separate us from each other on the inside and from our key constituencies on the outside."

What Welch said was just a practitioner's "dream". For academics, boundaryless is not a precise notion. Boundary is ever present. It is up to people to manage across and within. Boundary may be "dissolved" to a certain extent but not "destroyed". Managers are right to break down the boundaries that make organisations rigid and unresponsive. But they are wrong if they think that doing so eliminates the need for boundaries altogether. Hirschhorn and Gilmore (1992) claim, "once traditional boundaries of hierarchy, function, and geography disappear, a new set of boundaries becomes important" and "these new boundaries are more psychological than organisational" (p105). Boundary management now is dealing with boundaries of authority, of task, of politics, and of identity. For each, there are positive and negative characteristic feelings, and necessary tensions to make it work. Correspondingly, these tensions are (1) lead, but remain in open to criticism; (2) specialise, but understand others' jobs; (3) defend one's interests without undermining the organisation; (4) feel pride without devaluing others.

Summary and Implication of Systems Boundary

We now summarise some characteristics endowed to the boundary from the above literature review.

Table 1. Multiple Dimensions of the Boundary Identityz

Contributors	Characterisation of boundary
Bateson	Difference.
Derrida	" <i>Différance</i> " — difference in both time and space.
von Bertalanffy	Permeable for energy and information exchange in an open system.
Katz and Kahn	Permeability as survivability for organisations
Churchman and Ulrich	Critical and dialectical nature.
Beer (VSM)	Separation between control and autonomy. Recursive nature.
Checkland	Bridge between systems thinking world and the real world.
Scott	Buffering and spanning strategies.
Cooper	Primary (i.e. non-supplementary) role in defining systems. Source of paradox and contradiction. Intermediary for system transforming.
Hirschhorn and Gilmore	For any boundary, there are positive and negative characteristics and tensions.
Chaos theory	Chaos state at the edge of stability and instability. Source of creativity.
Taoism	Dynamic, dialectic, recursive and paradoxical natures as shown at the division between Yin and Yang.

The concept of boundary is rooted upon the concept "difference". Bateson discusses the boundary in a map to illustrate how the difference in space dominates our mind. Derrida's *différance* is one step further with meaning in both space and time. *Différance* can be interpreted as a means of Derrida's famous "deconstruction" attempt, and can be identified as being in the endless process of dividing itself.

The boundary in open systems theory is studied as a physical property and it is described as permeable for exchanging information and energy between organic and natural objects and their environments. Churchman and Ulrich focus on the boundary judgment in social systems whereby the distinction between the involved and the affected in the decision-making process is very critical. Also, to respond to the critique that the systems approach is losing its identity in the endless conceptual expansion, Churchman assures the systems boundary is specified eventually in the unfolding interactions between systems approach and its enemies. Ulrich, too, requires boundary to be set but claims that the value judgments made in doing so should be explicit.

In Beer's viable system, the systems boundaries among sub-systems are the balancing points between control and autonomy. It is the best place to leverage the tension between two functions, through feedback across these functions. Since viable system is recursive by enclosing a next level viable system (system 1), systems boundary involved is seen also to be recursive in nature.

Checkland's boundary concept is embedded in the interpretive inquiring process which is summarised in a the intervention methodology SSM. The crucial boundary is the interface between the systems thinking world and the real world, whereby issues in the real world are expressed, conceptualised and modelled. Also in the interface, the comparison and debate between conceptual models and the perceived facts happens in the form of recurrent interactions with multiple perspectives. In this sense, Checkland differentiates interpretivist systems boundary from the positivist one.

Organisational theorists (e.g. Katz and Kahn) started by adopting the permeable boundary from open systems theory. Boundary buffering and spanning (Scott) came from the same direction but are the first two "strategies" identified for activity at boundary itself (not as an attachment of a system). Cooper bases his theories on the exploration of Bateson's difference and Derrida's *différance*. On one hand, He claims the primary (non-

supplemental) role of boundary as the source of paradoxes and contradictions; on the other hand, he hints the idea that boundary can be used for network interlocking in the transformation-displacement process of system. Boundary-spanning is emphasised in today's network age.

Hirschhorn and Gilmore, from the viewpoint of consultants and practitioners, re-identify some necessary boundaries and discuss their positive and negative characteristics after rigid boundaries are dissolved in many organizations through the "boundaryless movement". This shows from another perspective that boundary is a ever present issue that cannot be ignored by claiming "just cross it".

The implication from chaos theory is that the boundary could be a chaotic state at the edge of stability and instability. Since there is a variety of beautiful form in the state, the boundary could be the triggering point of innovation and system renewal.

Taoism, though developed in ancient times endows boundary with rich meanings that are revealed in exploring the dynamic interactions of Yin and Yang. The relationship of Yin and Yang is dialectical, paradoxical and recursive in nature. In Taoism, Oneness itself is a chaotic state; embedded in it, Yin and Yang (as opposite conceptual poles) move into and out of each other in a cyclic movement which in turn creates the universe.

CONCLUSION

Based on an extensive literature review, this paper summarizes the characteristics of systems boundary from a multi-disciplinary perspective. Systems thinkers recognise that the human mind has a tendency to ignore the whole. Yet the mind can start to appreciate the essential quality of the whole by seeing the world through the eyes of others. What we see are the same essence but from a different angle. Systems thinking without system boundaries will fall into the trap of continual expansion and eventual loss of meaning. Hence, the conceptual whole is gained in the exercise of the crossing, setting, buffering, spanning, and dissolving of both mental and physical boundaries.

Emery and Trist (1965) hinted at a "third" law in addition to the system law and the environmental law, by saying that, "the laws connecting parts of the environment to each other are often incommensurate with those connecting parts of the organisation to each other, or even with those which govern the exchanges". For Ackoff (1981), the really crucial boundaries (though invisible) are those among ideal, objective, goal and target. "To interact" is the eventual solution to cross these boundaries. Following Ackoff's idea, we believe the systems boundary like any systems issue, cannot be "solved" or "resolved", but can only be "dissolved" in a multi-dimensional boundary unfolding and mapping, in the recurrent interactions across boundaries.

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