11. A unified open systems model for explaining organisational change

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Abstract

This paper presents an approach to developing a unified conceptual model to describe and explain change in organisations, viewed as complex systems. The authors propose a model that brings together the traditional open systems model (based on principles of homeostasis, steady state, and cybernetics) and the dissipative systems model (based on thermodynamic non-equilibrium principles) to explain distinctively different phases of change. Gradual and incremental change can be explained by using the traditional open systems model, whereas dramatic and discontinuous change can be explained by the adoption of the dissipative systems model. These two phases of change occur naturally, depending on the nature and pattern of external and internal disturbances. Since the implementation of any information system involves some degree of organisational change, it would be valuable to the IS community to more clearly understand organisational change processes, thereby increasing the possibility of success.

Introduction

We currently dwell in a turbulent environment, one in which change constantly occurs and elements in the environment are increasingly interrelated (Emery and Trist, 1971; Terreberry; 1971; Robbins, 1990). The nature of change has recently tended to be revolutionary rather than evolutionary. One possible explanation is that the progress in information and telecommunication technologies, together with the inception of the Internet as a global computer network, has made the world substantially more interconnected than ever before. This acts as a catalyst in fostering further change so that change is now the norm rather than an occasional occurrence. This poses an immense challenge to academics and practitioners alike in successfully understanding and managing organisations as complex entities.

One of the prime sources of change in organisations is the introduction of new technology (especially information technology) into the organisation (Davenport, 1993; Gasco, 2003; Bertschek and Kaiser, 2004). Recently, the concept of re-engineering was introduced as a means of achieving a dramatic improvement in organisations' productivity and effectiveness by radically redesigning business processes through extensive application of information technology (Hammer, 1990; Hammer and Champy, 1993; Davenport, 1993). However, the chance that a re-engineering project can be successfully implemented in an organisation is surprisingly low, as organisational inertia and resistance to change must be overcome, and the ability to do this varies from one organisation to another (Robbins, 1990). Moreover, successful implementation of information systems projects in organisations depends on factors apart from technological ones (Johnson, 1996). Therefore, an alternative and distinctive organisational change model is proposed here.

Like living systems, organisations experience gradual, incremental types of change as reflected in their growth, maturity, and decline (Miller, 1978). In addition, they experience an oscillatory type of change due to the operation of feedback mechanisms that work to achieve a steady state or homeostasis (Bertalanffy, 1973; Kramer and De Smith, 1977; Skyttner, 2001). However, if the environmental changes are so great that they are beyond the limits within which the homeostatic mechanisms can cope, the organisation as a system has to transform itself into another form that is more suitable to the new environment. Thus a pattern-breaking type of change can be expected (Leifer, 1989). This kind of change does not occur regularly, although evidence reveals that it now occurs more frequently since the progress in telecommunication and transportation technology acts as a catalyst in fostering the rapid evolution of economic, social and political environments (Rosenberg, 1986; Zuboff, 1988; Ohmae, 1991). These developments are making the world smaller in terms of space and time, and the effects of change in one part of the world can be felt rapidly in the others.

Changes in an organisation consist of two distinctive kinds, namely 'convergence' which is typified by an incremental, gradual and adaptive type of change, and 'reorientation' which is characterised by a disruptive, discontinuous and transformational type of change (Tushman and Romaneli, 1985, 1994; Tushman and O'Reilly III, 2002). We propose that neither of these models of types of change is, alone, either adequate to explain changes in complex organisations, or can completely explain the phenomena that occur in the change process. Our belief is that the traditional open systems model, which focuses on incremental change, and the dissipative systems model, which focuses on disruptive change, should be applied together as a unified model in order to account for all types of organisational change.

Closed systems and organisational theories

Before an extensive analysis of theories of open systems is conducted, it is useful to briefly consider some attributes of closed systems. In physics, a closed system is one where there is no exchange of matter between the system and its environment (Cengel and Boles, 2002). However, Kramer and De Smith (1977) define a closed system as a system that has no interaction at all with its environment. But they explain further that a system can be deliberately considered as a closed one by researchers if the relations that exist between the system and its environment are disregarded for the sake of simplicity in their analysis. For example, a production or assembly line, which is built on the theory of scientific management and operations research, can be treated as a closed system if it is insulated from fluctuations in demand and supply (environmental contingencies) through the stockpiling of raw materials and finished-goods to keep it in a relatively static environment.

Even though it is impossible to treat a work organisation as a completely closed system, in the past several organisational theories have assumed this view (Robbins, 1990; Scott, 1998). Between 1900 and 1930, the most dominant theories, which were based on closed-rational system models, were Taylor's scientific management approach, Weber's model of bureaucracy, and Fayol's administrative theory. From the 1930s through the 1950s, the most influential theories were based on a new perspective of closed-natural system models, such as Barnard's theory of cooperative systems and Mayo's human relations model. It is reasonable to say that the ideas of scientific management and bureaucracy are rooted in engineering where the system designer believes that, through proper design and without referring to external factors, a purposive system will perform in an efficient and effective manner. This belief has become the foundation of the machine metaphor or the mechanistic organisation (Morgan, 1997).

A prevalent example of a management system built on a closed system model is a machine bureaucracy, which is still, to various degrees the prevailing paradigm in most organisations (Brown, 1992; Beetham, 1996; Du Gay, 2000). The main objective of a bureaucracy is to promote efficiency and control in systems through the following: a fixed division of labour; a hierarchy of offices; a set of general rules that govern performance; a separation of personal from official property and rights; selection of personnel on the basis of technical qualifications; and employment viewed as a career by participants (Scott, 1998). From an engineering viewpoint, it is a superbly designed system based on technical rationality, aimed at maximising operational efficiency and control. However, the emphasis on internal operational efficiency without referring to external factors can result in system-environment misalignment. In addition, the sole concentration on control without flexibility may well cause poor adaptation, which leads to unsatisfactory performance in the long run.

Closed systems and change

One possible explanation for the existence of organisations that continuously remain in a steady state condition is that they reside in a relatively static environment (e.g. some not-for-profit organisations). When the environment is relatively static, stable, and predictable, interactions and relationships between the organisation and its environment are trivial and, thus, can be ignored or otherwise managed (Robbins, 1990). The closed system model was universally adopted in management theory development during the early 20th century. However, the environment has changed dramatically over the past century and the direction of change is toward an increase in both complexity and dynamism (Neumann, 1997; Robbins, 1990). A model that was valid in the past might not be effective in describing, explaining, and predicting organisational phenomena in a changing context. For example, the Just-in-Time (JIT) inventory system increases the alignment between the production system and its environment, giving a substantial increase in operational efficiency and a reduction in inventory cost (Chase and Aquilano, 1989; Greene, 1997; Gaither and Frazier, 1999).

If the human or work organisation is assumed to be a closed system, the direction of change should go toward an equilibrium state in which entropy will maximised, according to the second law of thermodynamics. In this case, the organisation as a system should deteriorate rather than prosper over time. The increase in entropy suggests that the organisation and order of the system will be degraded and the system will run down.

Open systems and organisation theories

It was realised, by the 1960s, that the assumption that organisations are closed systems was no longer tenable. The fact that organisations exchange resources with their environment is incompatible with the assumption in the closed systems model of lack of interaction and interdependence between the system and its environment. This realisation could possibly be explained by the increase in the complexity and dynamism of the environment (e.g. technological, social, economic, and political) and the impact of these changes on organisations required organisational theorists to rethink the validity of the previous model and its assumptions. This led to the inception of a new generation of theories, which were based on the open systems model, that were dominant during the 1960s and through the 1970s.

Characteristics and mechanics of open systems

The concept of equilibrium and steady state conditions need to be clarified before we go further into how open systems operate. In a closed system, equilibrium is achieved when opposing variables in the system are in balance (Miller, 1978). In addition, the equilibrium can be static or dynamic. The former is commonly found in closed systems while the latter is a property of an open system. Since living systems are open systems, with a recurrent alteration of fluxes of matter, energy, and information, their equilibrium is dynamic. Miller (1978) termed the dynamic equilibrium a 'flux equilibria' or 'steady state'. The term dynamic equilibrium has, however, also been utilised interchangeably in both closed and open systems (Bertalanffy, 1973). We argue that both closed and open systems can exhibit equilibrium; however, in the latter case, the equilibrium is 'quasi' rather than being a true one as in closed systems.

In the previous paragraph, a steady state was characterised as a dynamic equilibrium that exists in open systems. According to Kramer and De Smith (1977), a steady state refers to an open system maintaining an unchanging state even when input and output are still in operation. This makes the system appear static to the observer despite the fact that the flow of resources through the system is dynamic and continuous. A popular example of this is the maintenance of the human body temperature at 37° Celsius. In this case, the amount of heat generated by the body's metabolism is kept equal to the heat lost to the environment. As a result, a constant body temperature can be maintained.

The most important quality of an open system is that it can perform work, which is unachievable in a closed system in an equilibrium state because a closed system in equilibrium does not need energy for the preservation of its state, nor can energy be obtained from it. In order for it to perform work, it is necessary that an open system is not in an equilibrium state. Nevertheless, the system has a tendency to attain such a state. As a result, the equilibrium found in an organism (or any open system) is not a true equilibrium, incapable of performing work. Rather, it is a dynamic pseudo-equilibrium (or quasi-equilibrium) kept constant at a certain distance from the true equilibrium. In order to achieve this, the continuous importation of energy from the environment is required (Bertalanffy, 1950, 1973).

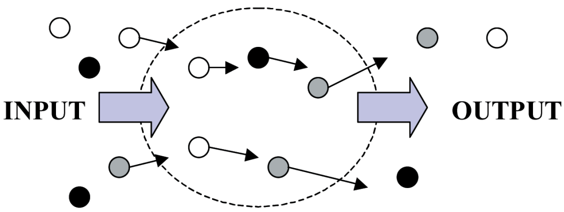
The homology between an open system and human or work organisations can be drawn from the chain of logic mentioned in the previous paragraph. A fictitious organisation, which is largely closed to the external environment, will eventually lose its alignment with the environment because only limited or no resources (i.e. materials, energy, and information) from the environment are allowed to cross the boundary into the organisation. This leads to a misalignment between organisational strategy-structure and the environment, which results in substandard performance as the acquisition and usage of resources become inconsistent with the demand from the environment. The organisation that persistently performs poorly will deteriorate over time and, we argue, is on the way to equilibrium according to the second law. On the other hand, a viable organisation needs a continuous inflow of new members for new ideas, skills and innovations, raw materials and energy to produce new products and/or services, and new information for reasonable planning, strategy formulation and coordination. Only the importation of these resources from the environment can keep it away from equilibrium and can allow it to perform its activities in a viable manner.

It should be noted at this point that the meaning of equilibrium as it is used here, is 'entropic equilibrium' in which equilibrium is maintained at the expense of structure (Grey, 1974; Van Gigch, 1978). In other words, the system's structure and organisation will deteriorate over time, according to the second law, if there is no importation of energy and materials from the environment and processing of information. Another type of equilibrium will be introduced in the next section.

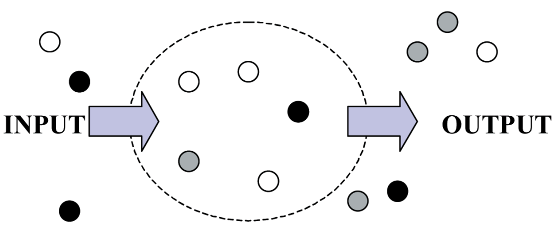
Homeostasis and the behaviour of open systems

It is necessary for many systems to maintain their equilibrium in changing environments or disturbances, otherwise they cannot function properly or their goals cannot be attained. In living systems, the process of self-maintenance or 'homeostasis' is essential to ensure their survival and viability. The term homeostasis is referred to by Flood and Carson (1993) as a process by which a system preserves its existence through the maintenance of its dynamic equilibrium. This equilibrium is termed 'homeostatic equilibrium' (Van Gigch, 1978). Thus, a mature organism as an open system appears to be unchanged over a period of time because there is a continuous exchange and replacement of matter, energy, and information between the system and the environment. Homeostasis can be explained mathematically as follows (Flood and Carson, 1993): If we define $x(t)$ as the state vector at time t and $x(t+s)$ as the state vector at time $t+s$, the preservation of the system's condition over a relatively short period of time can be represented by a statement: $x(t) = x(t+s)$, which means that at $t+s$, the identity of the organism may appear to be unchanged; however, the actual materials that constitute the organism at time t will be partially or entirely replaced by time $t+s$. This can be shown graphically as in Figure 11.1.

Figure 11.1. Homeostasis in an open system at *t* and *t+s*. Adapted from Flood and Carson (1993).



(a) An open system at t



(b) An open system at t+s

Homeostasis is not only one of the most important properties of any living organism, but is also readily applicable to human or work organisations treated as open systems. The organisation needs to recruit new employees to replace those who retire; it also needs raw materials, energy, and information for use in its processes and operations to maintain a steady state. In fact, an organisation that appears externally static and unchanged to outside observers is internally in a state of flux, in a state of dynamic equilibrium.

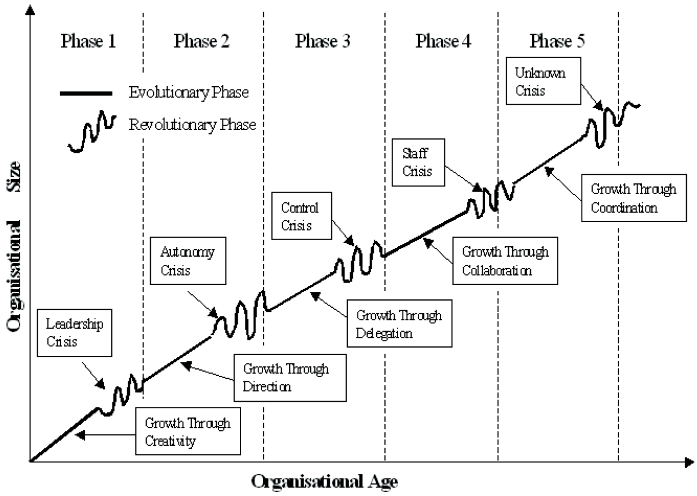
Another significant aspect of an open system in a state of dynamic equilibrium is that it relies on feedback mechanisms to remain in that state. Based on Boulding's system hierarchy, which classifies the system according to its complexity, it is not surprising to find that properties exhibited by systems lower in the hierarchy are also found in those higher in the hierarchy because the latter are built on the former (Boulding, 1956). Therefore, a system that is classified as an open system would possess all the qualities that belong to the system at a cybernetic (or self-regulated systems) level. The behaviour of open systems is, to a great extent, determined by the feedback mechanisms present in them. There are two types of feedback that operate in most systems, namely negative and positive. Negative feedback reduces or eliminates the system's deviation from a given norm, so a negative feedback mechanism tends to neutralise the effect of disturbance from the environment so the system can maintain its normal course of operation. On the other hand, positive feedback amplifies or accentuates change, which leads to a continuous divergence from the starting state. Positive feedback works together with negative feedback in living systems (e.g. in organisms, and organisations too, both types of feedback are present during growth even though the net result is positive). However, the operation of positive feedback alone will eventually result in the system's disintegration or collapse. Negative feedback plays the key role in the system's ability to achieve a steady state, or homeostasis.

Organisational life cycle: growth, maturity, decline and death

Organisations exhibit a similar, though not identical, life-cycle pattern of changes to living organisms. They grow, mature, decline, and eventually pass away. However, there are some differences that require attention. Firstly, the duration of each stage is less precise than that of typical organisms. In human beings, physiological growth reaches its climax at about the age of 25 whereas the growth phase of an organisation can vary to a great extent. Secondly, the mechanics upon which changes are based are different. Living organisms are typical biological machines with their own physics and chemistry, while organisations are not. According to Boulding (1956), organisations are at a higher level of complexity than living organisms.

Genetic factors and available resources both influence growth in organisms. Organisms develop from fertilisation to maturity through a programmed or predetermined genetic code, a process termed 'ontogenic development' (Ayres, 1994). Apart from this, it is also necessary that the organism acquire sufficient necessary resources from the environment to sustain its life and remain viable. Although the concept of ontogenic development may not be directly applicable to the growth of real organisations due to the difference in basic constituents and mechanisms (i.e. biological vs. socio-technical), there is a similar idea upon which the description of growth in organisations can be based. Greiner (1972) proposed a growth model that explained the growth in business organisations as a predetermined series of evolution and revolution (Figure 11.2). In order to grow, the organisation is supposed to pass through a series of identifiable phases or stages of development and crisis, which is similar, to some degree, to the concept of ontogenic development. Thus, it is interesting to see that systems at different levels of complexity (Boulding, 1956) can exhibit a similar pattern of change. This is also consistent with General System Theory, which attempts to unify the bodies of knowledge in various disciplines (Bertalanffy, 1973).

Figure 11.2. The five phases of organisational growth (adapted from Greiner, 1972).



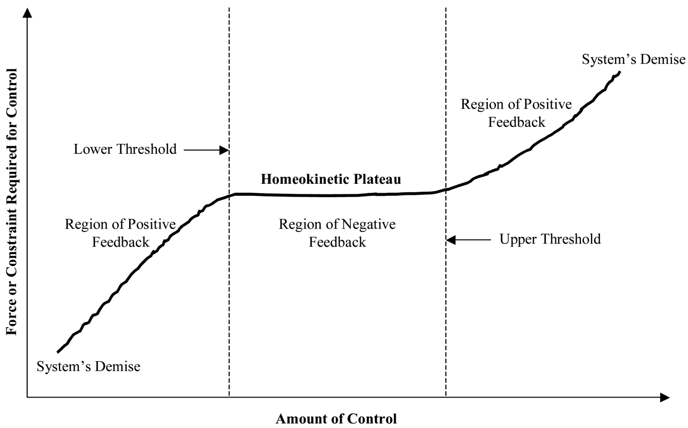
Greiner's model suggests how organisations grow, but the basic reasons behind the growth process and its mechanics remain unclear. As mentioned previously, growth in a living organism is a result of the interplay between the ontogenic factor and the environment. Here, positive feedback plays a vital role in explaining changes in a living system. Although both positive and negative feedback work in concert in any living system, in order to grow (or to effect other changes in a system), the net type of feedback must be positive (Skyttner, 2001). In organisms, starting at birth, the importation of materials and energy from the environment not only sustains life but also contributes to growth. As they keep growing, so does their ability to acquire resources. This means that the more they grow, the more capacity in resources acquisition they have and the more resources they can access. This growth and the increase in resource acquisition capabilities provides a positive feedback loop, which continues until the organism matures. The positive feedback loop will be active again when the organism starts to decline, which will be mentioned later.

An analogy can be made between the process of growth in a business organisation and that in an organism (provided that the business organisation pursues a growth strategy). If the resources in a niche or a domain are abundant, a business organisation in that niche is likely to run at a profit (provided that the relevant costs are under control). An increase in profit results in an improvement in return on investment (ROI), which tends to attract more funds from the investors. The firm can use these funds to reinvest for expansion, to gain more market control, and make even more profit. This positive feedback will continue until limiting factors (e.g. an increase in competition or the depletion of resources within a particular niche) take effect.

A living system cannot perpetually maintain growth, nor can it ensure its survival and viability forever. After its growth, the system matures, declines, and eventually ends. This can be explained by using the concept of 'homeokinesis' (Cardon, et al., 1972; Van Gigch, 1978, 1991; Skyttner, 2001). It has already been argued that one of the most important characteristics of any living system is that it has to be in a homeostatic, or dynamic, equilibrium condition to remain viable. Nonetheless, the fact that a living system deteriorates over time and eventually expires indicates that there is a limit to this. Rather than maintaining its dynamic equilibrium, it is argued that a living system is really in a state of disequilibrium, a state of evolution termed 'homeokinesis'. Rather than being a living system's normal state, homeostasis is the ideal or climax state that the system is trying to achieve, but that is never actually achievable. Homeostasis can be described in homeokinetic terms as a 'homeokinetic plateau' (Figure 11.3) – the region within which negative feedback dominates in the living system. In human physiology, after age 25 (the physiological climax state), the body starts to deteriorate but can still function. After achieving maturity, it seems that a living system has more factors and contingencies to deal with, and that require more energy and effort to keep under control. Beyond the 'upper threshold' (see Figure 11.3), it is apparent that the system is again operating in a positive feedback region, and is deteriorating. Even though the living system is trying its best to maintain its viability, this effort, nonetheless, cannot counterbalance or defeat the entropically increasing trend. The system gradually and continuously loses its integration and proper functioning, which eventually results in the system's expiry.

Although we argue that the concept of homeokinesis and net positive feedback can also be applied to the explanation of deterioration and demise in organisations, as noted earlier it is very difficult to make a direct homology between changes in organisms and changes in organisations. Rather than being biological machines, which can be described and explained, to a large extent if not (arguably) completely, in terms of physics and chemistry, organisations are much more complex socio-technical systems comprising ensembles of people, artefacts, and technology working together in an organised manner.

Figure 11.3. Control requires that the system be maintained within the bounds of the homokinetic plateau. Adapted from Van Gigch (1991).



As mentioned earlier, after its maturity, the organism gradually and continuously loses its ability to keep its integration and organisation under control (to counterbalance the entropically increasing trend) and this finally leads to its demise. While this phenomenon is normal in biological systems, even though organisations in general may experience decline and death (as many empires and civilisations did in history), it appears that the entropic process in organisations is less definite and more complicated than that in organisms. Kiel (1991) suggests that this dissimilarity can be explained in terms of systems' differences in their abilities to extract and utilise energy, and the capacity to reorganise as a result of unexpected and chaotic contextual factors. This suggests that biological systems are less resilient and capable than social systems with respect to natural decline.

This may be reflected in the difference in timing and duration of each of their developmental phases. For example, while the duration of each phase in the life cycle, and the life expectancy, are relatively definite for a particular type of organism, such duration is very difficult, if not impossible, to specify for organisations. A small business may, on average, last from several months to a number of years whereas, in contrast, the Roman Catholic Church has lasted for centuries (Scott, 1998). It may be that the size and form of the organisation are influential factors in this respect, a proposition that still requires further empirical investigation.

To be in the region of the homeokinetic plateau, the proper amount of control for a well-functioning and sustainable living systems must be present, and similarly for organisations. Too little control will lead to poor integration and a chaotic situation whereas too much control results in poor adaptation and inflexibility.

The dissipative systems model

The theory of dissipative structure upon which the current discussion is based can be treated as the open systems model extended with a capability to continuously impose a revolutionary change or transformation.

The theory of dissipative structure

Pioneered by the Brussels school of thought in the 1970s (Prigogine, 1976; Nicolis and Prigogine, 1977, 1989; Prigogine and Stengers, 1984), this theory is firmly rooted in physics and chemistry. Nevertheless, it was later applied to urban spatial evolution (Allen and Sanglier, 1978, 1979a, 1979b, 1981), organisational change and transformation (Gemmill and Smith, 1985; Leifer, 1989; Macintosh and Maclean, 1999), changes in small groups and group dynamics (Smith and Gemmill, 1991), and political revolutions and change in political systems (Artigiani, 1987a, 1987b; Byeon, 1999).

Dissipative structure in physical systems

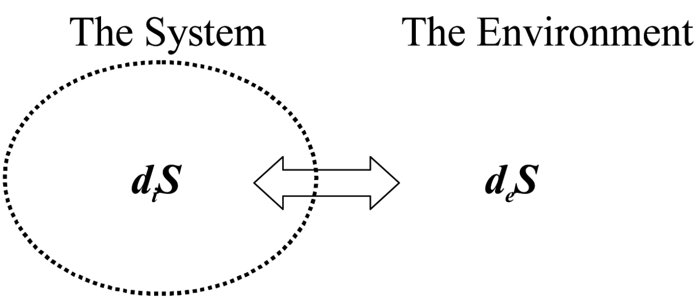
The most prominent example of dissipative structure in a physical system is convection in a liquid (Nicolis and Prigogine, 1977; Jantsch, 1980; Prigogine and Stengers, 1984). If cooking oil is heated in a shallow pan, the following macroscopic changes occur. Firstly, while the temperature of liquid is relatively uniform, heat is transmitted through the body of liquid by means of conduction in which the molecules' heat energy (molecular vibration) is transmitted to neighbouring molecules via collision without major change of position. We can say that the system is still in a thermodynamic equilibrium. Next, as the pan is heated further, the temperature gradient between the upper and lower portion of the oil in the pan becomes more pronounced and thermal non-equilibrium increases. At a certain temperature gradient, convection starts and heat is then transferred by the bulk movement of molecules. Evidently, however, the surrounding environment at first suppresses the smaller convection streams, but beyond a certain temperature gradient, the fluctuations are reinforced rather than suppressed. The system moves into a dynamic regime, switching from conduction to convection, and a new macroscopic order called 'Benard cells' (i.e. a pattern of regular hexagonal cells that appear on the surface of liquid) emerges, caused by a macroscopic fluctuation and stabilised by an exchange of energy with the environment. Such a structure is called a hydrodynamic dissipative structure, and is a version of spatial structure (Haken, 1980).

Order in a non-equilibrium state

As mentioned earlier, open systems make an effort to avoid a transition into thermodynamic equilibrium by a continuous exchange of materials and energy with the environment. By doing this, a negative entropy condition can be maintained. It has been understood for a long time that entropy is a quantification of randomness, uncertainty, and disorganisation, and negative entropy therefore corresponds to (relative) order, certainty, and organisation (Bertalanffy, 1973; Kramer and De Smith, 1977; Nicolis and Prigogine, 1977; Prigogine and Stengers, 1984; Miller, 1978; Van Gigch, 1978, 1991; Flood and Carson, 1993). However, the mechanics underlying this idea had not been clear until it was explained in the work of Nicolis and Prigogine (1977), Prigogine and Stengers (1984), and Jantsch (1980) in the theory of dissipative structure and order that exists in the non-equilibrium condition.

According to the theory of dissipative structure, an open system has a capability to continuously import free energy from the environment and, at the same time, export entropy. As a consequence, the entropy of an open system can either be maintained at the same level or decreased (negative entropy), unlike the entropy of an isolated system (i.e. one that is completely sealed off from its environment), which tends to increase toward a maximum at thermodynamic equilibrium. This phenomenon can be represented in quantitative terms as follows (Nicolis and Prigogine, 1977; Jantsch, 1980; Prigogine and Stengers, 1984). According to the second law of thermodynamics, in any open system, change in entropy dS in a certain time interval consists of entropy production due to an irreversible process in the system (an internal component) d_iS and entropy flow due to exchange with the environment (an external component) d_eS. Thus, a change in entropy in a certain time interval can be represented as $dS = d_eS + d_iS$ (where $d_iS > 0$). However, unlike d_iS, the external component (d_eS) can be either positive or negative. Therefore, if d_eS is negative and as numerically large as, or larger than, d_iS, the total entropy may either be stationary ($dS = 0$) or decrease ($dS < 0$). In the former case, we can say that the internal production of entropy and entropy exported to the environment are in balance. An open system in a dissipative structure sense can be viewed as shown in Figure 11.4.

Figure 11.4. An open system's entropy production and dissipation.



It can be concluded that order in an open system can be maintained only in a non-equilibrium condition. In other words, an open system needs to maintain an exchange of energy and resources with the environment in order to be able to continuously renew itself.

Entropy and sustainability of dissipative systems

The internal structure and development of dissipative systems, as well as the process by which they come into existence, evolve, and expire, are governed by the transfer of energy from the environment. Unlike isolated systems (or closed systems in a broader sense), which are always on the path to thermal equilibrium, dissipative systems have a potential to offset the increasing entropic trend by consuming energy and using it to export entropy to their environment, thus creating negative entropy or negentropy, which prevents the system from moving toward an equilibrium state. A negentropic process is, therefore, the foundation for growth and evolution in thermodynamic systems.

For dissipative systems to sustain their growth, they must not only increase their negentropic potential, but they must also eliminate the positive entropy that naturally accumulates over time as systems are trying to sustain themselves. The build up of the system's internal complexity as it grows is always accompanied by the production of positive entropy ($d_iS > 0$), which must be dissipated out of the system as waste or low-grade energy. Otherwise, the accumulation of positive entropy in the system will eventually bring it to thermodynamic equilibrium, a state in which the system cannot maintain its order and organisation (Harvey and Reed, 1997).

Implications for organisations

Although the argument so far is fundamentally based on chemical or biological systems, we argue it also applicable to the organisation as an open system. It is suggested by Leifer (1989) that the net resource used by an organisation can be viewed as being divided into two parts. First is that concerned with the maintenance of the internal environment, and second, that which is transacted with the external environment. The former is treated as the change of entropy due to necessary maintenance and support processes (d_iS), which is always positive due to the nature of indirect costs, and the latter as the change of entropy in the input-transformation-output process (d_eS), which may be positive or negative (e.g. a firm may experience profit or loss). It is suggested, further, that d_iS refers to all the activities that are necessary to keep the organisation maintained and supported (e.g. management, administration, research and development, etc.) and d_eS refers to all the activities where there is interaction with the environment (e.g. purchasing, selling, recruiting, etc.) and production of products and services. We further maintain that, in order for the organisation to remain viable, the flow component of entropy must be negative and greater in magnitude than that of the maintenance and support component since the support and maintenance activities always result in a net drain or loss to the organisation due to the exploitation of resources, but the input-transformation-output process (i.e. production and sales activities) may result in a net gain for the organisation if its earning is greater than its cost (Leifer, 1989). In summary, we conclude, albeit perhaps at a metaphorical level, that in order for an organisation to maintain its order it must be in a non-equilibrium state.

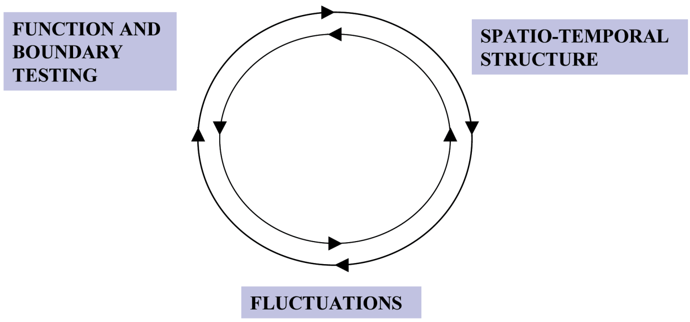
Order through fluctuations and system transformation

This section will address how fluctuations can lead to significant change in systems, which results in higher degrees of order and complexity, and how this relates to the concept of the systems' transformation and self-organisation. Fluctuation in this case can be defined in general as a spontaneous deviation from average behaviour (Nicolis, 1979). In chemistry, it can be defined as follows (Jantsch, 1980, pp. 42-3):

> The fluctuations referred to here are not fluctuations in concentration or other macroscopic parameters, but fluctuations in the mechanisms, which result in modifications of kinetic behaviour (e.g. reaction or diffusion rates). Such fluctuations may hit the system more or less randomly from without, as through the addition of a new reaction participant or changes in the quantitative ratios of the old reaction system. But they may also build up within the system through positive feedback, which, in this case, is called evolutionary feedback.

However, the theory of dissipative structure has the potential to be applied to systems beyond those of concern to natural science (Nicolis and Prigogine, 1977; Jantsch, 1980; Prigogine and Stengers, 1984). In this theory, fluctuations play a vital role in causing significant system change because, when a system is driven to a critical instability point (bifurcation point or point of singularity), the non-equilibrium system can be regarded as testing various configurations by fluctuations, which results in a new space and time structure (Haken, 1984, 1987). In other words fluctuations, which lead to instabilities, may be introduced to the system in order to yield new types of function and structure. In this sense, no system is structurally stable. Rather, the evolution of dissipative structure is a self-determining sequence of its function and boundary testing, spatio-temporal structure, and fluctuations (Nicolis and Prigogine, 1977; Allen, 1981) as illustrated in Figure 11.5.

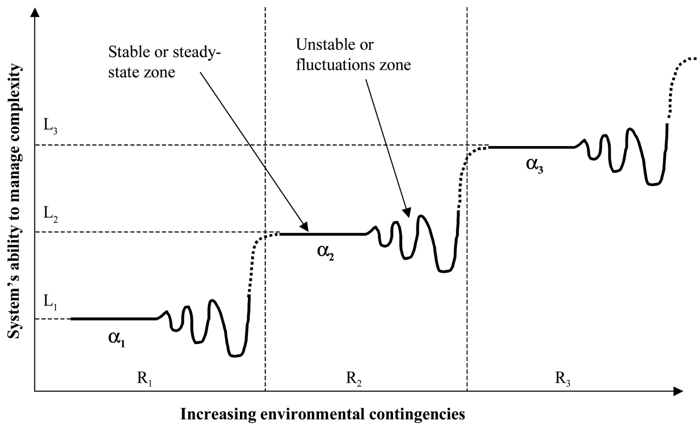
Figure 11.5. The role of fluctuations in creating order.



In addition, the source of fluctuations can be internal or external (Allen, 1981). In organisations, sources of internal fluctuations may come from the action of leaders or managers or the dynamic of power and political struggle and activities. External sources may arise from both the macro-environment (i.e. economic, technological, political, and socio-cultural) and the micro-environment (i.e. customers, suppliers, competitors, etc.).

Figure 11.6 shows how macroscopic order can be created through fluctuations and how it is related to the system's ability to cope with complexity and environmental contingencies. At α_1 an organisation, as a complex system, has a capacity to cope with complexity at level L_1, within a range of environmental contingencies R_1. As the environmental contingencies increase, the system can still maintain a steady state, a state within which negative feedback operates. This is represented by the straight-line portion of the graph within range R_1. However, as the environmental contingencies keep on increasing, the system starts to destabilise and fluctuations start to occur. If fluctuations are accentuated, this is because positive feedback is now dominating in the system. This process will continue until it reaches a bifurcation point (or point of singularity), where the system either self-organises and transforms (evolves) into a new form (i.e. new spatio-temporal structure), which is more complex and more capable of coping with the new level of complexity (a state of α_2 at level L_2) and the next range of increased environmental contingencies R_2, or it deteriorates and runs down because it fails to self-organise. This process will continue as long as the system succeeds in self-organising itself to handle the increase in environmental contingencies (i.e. it can achieve a state of α_2 , α_3 , …).

Figure 11.6. System transformation and production of macroscopic order.



Based on the theory of dissipative structure, the system needs energy from the external environment to achieve a higher-level state or to be transformed into a new form with higher complexity and more capability to deal with increased environmental contingencies. In organisational theory, energy can be considered analogous to resources, efforts, change strategy, leadership, knowledge and information, and power required to effect fluctuations, which result in a transition from one state to another.

Model synthesis and discussion

The justification for adopting a unified or integrated approach in modelling change and evolution in organisations comes from the pattern of change characterised by the Theory of Punctuated Equilibrium, which was originally proposed in the field of palaeontology and biological evolution in the mid-20th century to explain a discontinuous change of patterns usually found in fossils (Mayr, 1942, 1982; Gould and Eldredge, 1977; Hoffman, 1989).

Theory of punctuated equilibrium and rationale for model synthesis

It is proposed in the Theory of Punctuated Equilibrium that biological species can remain unchanged, or only have a marginal change in their form, over a lengthy time period. This period is called 'stasis'. However, in order to survive and avoid extinction when the environment becomes unfavourable, the pace of evolutionary change needs to be accelerated. This results in a relatively discontinuous change in the species form. In other words, a new species comes into existence. Thus, according to this theory, a pattern of relatively long and stable periods punctuated by rapid and discontinuous change is typical of natural biological systems.

A similar pattern of change occurs in organisational dynamics (e.g. Miller and Friesen, 1984; Tushman and Romaneli, 1985, 1994; Gersick, 1988, 1991). As mentioned earlier, change in organisations is often characterised by a lengthy period of incremental, gradual and adaptive change (convergence) alternated or punctuated by a short period of a widespread, discontinuous and transformational change (reorientation). Modelling both phases of change thus poses a challenge because the traditional open systems model, which is based on the concepts of homeostasis and steady state, can only describe and explain the 'stasis' or 'convergence' phase. It does not encompass the type of change that occurs in 'transformational' or 'reorientation' phases. Consequently, we incorporate the theory of dissipative structure into the model.

Homeostasis, adaptation, and transformation

The degree of systemic change depends on the magnitude of environmental contingencies or external fluctuations although we have also argued that internal fluctuations play a vital role in inducing change in complex systems. Based on the argument made previously in the open systems and dissipative structure model, the organisation as a complex system can neither always maintain itself in a steady state (or homeostasis) nor keep on transforming without reference to the magnitude of fluctuations or disturbances that impinge upon it (see Tushman and Romaneli, 1985 for more details).

It is much more difficult for major transformational change to occur, or be implemented, because it typically involves a profound reformulation of the organisation's mission, structure and management, and fundamental changes in the basic social, political, and cultural aspects of the organisation (Levy, 1986; Levy and Merry, 1986). Hence, the concept of transformation covers both operational processes and psychological dimensions of the organisations. According to the theory of dissipative structure, transformational change requires energy (both human and non-human) to push the organisation across the instability threshold by means of necessary fluctuations, from within and without, to inflict a morphological change. In contrast, the concept of adaptation deals only with the modification of the system's structure or structural properties in such a way that the functional properties of the system are left largely or entirely unaltered when facing environmental disturbances (Van Gigch, 1978). Therefore, organisations as systems can only maintain their steady state or remain in a homeostatic equilibrium.

Adaptability is related to organisational structure in that it is about bringing the organisation into harmony with the changing environment, and the adaptive function works in two directions. First, it modifies internal structures to correspond with external changes, and second, it attempts to control the environment (Van Gigch, 1991). Moreover, the concept of adaptation is not limited to structural change but also relates to other factors as well (e.g. procedures and technology).

Figure 11.7. Punctuated equilibrium model showing adaptive (convergence) phase A and transformational (reorientation) phase B.

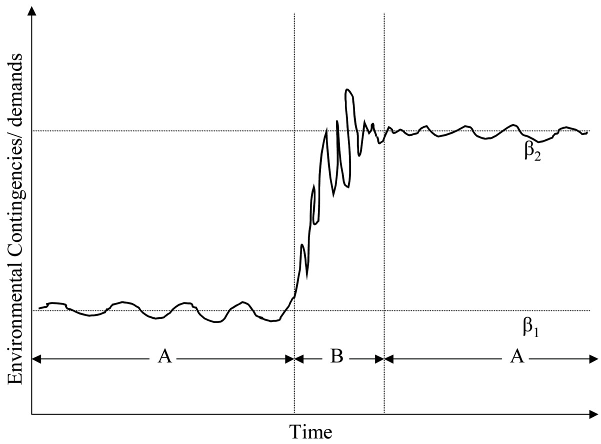


Figure 11.7 portrays how homeostasis, adaptation and transformation constitute the punctuated equilibrium model, and how they are interrelated. The graph represents the systemic behaviour, caused by the interaction among the organisation's subsystems and between them and the external environment. The pattern of such interaction is fundamentally determined by the system's structure (Cavaleri and Obloj, 1993) and can be measured by the system's output (Kramer and De Smith, 1977). The interaction between organisations and their environment results in variation in the system's behaviour. Phase A represents a system in a convergence period (β_1), which is mainly typified by its maintenance of a homeostatic condition (or steady state) – a condition in which the system is attempting to realign or adapt itself to the minor changes in the environment. Phase B represents a reorientation, which is characterised by a discontinuous and disruptive change that results in a reformulation of the organisation's basic constituents (i.e. structure, strategy, process/technology and psychological component) and is transient in nature. If the transformational change is successful the organisation will attain another equilibrium state (or convergence period) β_2 and remain in this state until conditions prompt another transformation. At β_2 a new organisational form, which is more complex and more capable of dealing with the environmental contingencies would be expected to have emerged. Therefore, the unified model, which constitutes the traditional open systems model and the dissipative structure model, can portray the whole change phenomenon.

Tools for system manipulation

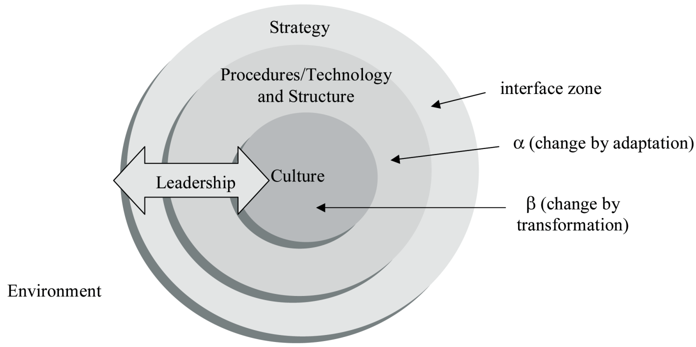
Organisations as complex systems can be manipulated by using the 'Management Systems Model' or MSM (Cavaleri and Obloj, 1993). The MSM has five systemic tools or factors, which are available for managers to manage or manipulate organisations in a desired way, namely:

1. Strategy
2. Structure
3. Procedures (technology/process)
4. Culture
5. Leadership

This model implies that each systemic tool should be applied in a harmonised and thoughtful manner to yield the best possible result as each particular tool or factor, when applied, would yield a different systemic result. While leadership and strategy are generally tools for inflicting changes or destabilisation on organisations, culture, procedures or technology and structure are systemic tools that are typically used to impose stability and regulation in the organisation. Moreover, the dynamic behaviour of the organisation is a result of the interplay between these endogenous factors and the environment and the interaction among these endogenous factors themselves (e.g. the interaction among strategy, leadership, structure, procedures and culture).

Rather than being considered as one of the manipulating tools, each factor can also be treated as an organisational property that can be changed to suit both external and internal contingencies. However, the effort required to change each property varies from one to another. For example, in adaptation, or shallow change, it is common for an organisation to realign itself with the changing environment by adjusting one or more of its properties (e.g. procedures/ technology, strategy, structure), which requires energy and effort, although relatively little compared to transformational change. Transformation (or deep change), however, requires a tremendous amount of energy, in terms of resources and effort, to change organisational culture and the political network as well (Svyantek and DeShon, 1993), as illustrated in Figure 11.8.

Figure 11.8. System interface and hierarchy of efforts required for change in an organisation.



In order for an organisation to operate successfully in a specific environment, it needs an interface between its subsystems and the environment. Organisational strategy is such an interface (Cavaleri and Obloj, 1993). The next layer (α layer) is the zone in which the interplay between technology, process and structure to carry out the organisation's operations exists and is active. Variables and factors in this zone are more sensitive to the disturbance from both internal and external sources and less difficult to manage and change than those from the inner core (or β zone). This ensemble of variables can be changed, with a certain effort, to achieve a proper alignment with the environment – a process called adaptation. Figure 11.8 also shows that all elements in both the α and β zones are exposed to the environment although the degree of exposure may vary (e.g. the production line is shielded from fluctuations in demand and supply to a certain extent). Lastly, the core of this diagram (or β zone) represents organisational culture, an element that is very influential for the survival and performance of the organisation (Peters and Waterman, 1982; Handy, 1995, 1999; Hofstede, 1997). The impact of culture on organisations is pervasive because it controls people's beliefs and shared values, and it is also transferable from one generation to the next. It is thus unlikely that culture can easily be changed or adjusted to conform to the changing environment. It requires a great deal of energy, effort and time to change the existing culture, and this is beyond the adaptive mechanism (Svyantek and DeShon, 1993). That is why we call a change at a cultural level a 'deep change.' As a consequence, it is proposed in this model that only transformation as a means of systemic change can have a profound effect on the organisation's culture.

As far as change is concerned, leadership is an essential factor in influencing change in other variables or factors. In Figure 11.8, leadership provides a linkage between the external environment, strategy and internal factors in both the α and β zones, and is also a source of power and authority required to effect change at various levels. Tushman and Romaneli (1985) assert that strong leadership is essential, especially for the reorientation or transformational phase of change, because not only must a clear vision be declared and communicated to organisational members, but also adequate power and authority is required to alter dysfunctional political networks and overcome resistance to change. Without strong leadership, it is unlikely that change can be implemented successfully in the organisation.

Organisational politics, power and control are related to self-awareness in systems. In this regard, organisations are treated as open-natural systems whose collective behaviour is characterised by political relationships and their interaction (Scott, 1998). This can make the system behave in an apparently irrational manner as groups or political networks work to protect and maintain control over their domains rather than pursue the organisation's mission and goal (Pfeffer, 1981). If the domain of interest to the organisation is under control, it is unlikely that the status quo will be changed and this contributes to a resistance to change. Organisational culture that incorporates this feature is thus potentially dysfunctional, and requires a transformational approach to change. However, the psychological aspect of self-awareness in systems is beyond the scope of the proposed model.

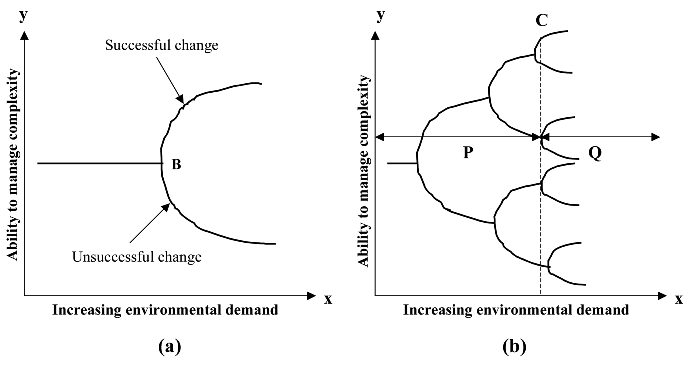
Bifurcations and self-organisation

As illustrated in Figure 11.6, if organisations can be successfully transformed, they become more sophisticated and their ability to survive and prosper in a more demanding environment is enhanced. A successful transformation means that organisations can self-organise into another form that is more complex and sophisticated. We propose that the increase in capability can be interpreted in a more concrete way as follows:

1. an increase in the ability to utilise resources and energy more effectively and efficiently;
2. an increase in the ability to seek, process, and make sense of information;
3. an increase in the organisation's knowledge as a result of learning and relearning from history.

Figure 11.6 can be displayed in another form as Figure 11.9 – a bifurcation diagram.

Figure 11.9. Bifurcation diagrams showing (a) the possibility of successful or unsuccessful change, and (b) change, entropy and self-organisation.



As the level of environmental contingency and turbulence increases, adaptation becomes less effective in coping with the change. If this situation continues until a critical point, which is called a bifurcation point (point B in Figure 11.9 (a)), is reached and the system is either radically changed to a more complex and sophisticated form with higher capability and capacity for survival (see also Figure 11.6, which displays only successful changes) or it fails to make a successful change and experiences a decline. The change displayed in diagram Figure 11.9 (a) represents only a simple version of organisational change using a bifurcation diagram. A more elaborate version, which explains change in organisation in detail, can be found in Guastello (1995, 2002).

Figure 11.9 (b) displays the relationship between the change in entropy level and the organisation change process. The distance between the y-axis and the vertical line C, which is represented by P, is the entropy build-up zone. An increase in entropy is necessary to bring the system to a far-from-equilibrium state. The area behind line C (represented by Q) is a chaotic zone in which self-organisation takes place and the system experiences a transformation to another state. This phenomenon corresponds to the development of the Benard cells mentioned earlier, in which a continuous supply of energy is required for the development of a new spatio-temporal structure.

Conclusion

Closed systems do not realistically represent real organisations because organisations are open rather than closed. Thus, any theories or models that treat organisations as closed systems are inadequate. Furthermore, although closed system models work best in a relatively static environment, such environments are rare and likely to become even less so.

Depending on environmental demand or contingency, organisations respond to perturbations in the environment either via an adaptation process, which can be viewed using an open systems model or homeostatic equilibrium model, or transformation, which is best viewed using a dissipative systems thermodynamic non-equilibrium model. Adaptation operates in response to limited environmental disturbances, but beyond these limits organisations need to transform themselves into more sophisticated forms that are more complex and capable of managing higher levels of environmental contingencies. However, a complex system must be in a far-from-equilibrium condition, which is characterised by instability, so that transformation can occur.

In adaptation, changes in the environment require that organisations modify some of their properties (strategy, structure, procedures or technology, and size) to be aligned with that environment. But adaptation cannot accommodate cultural change, which involves changing of people's beliefs held at a deep level. When organisations have to cope with an extremely high environmental contingency, transformation, which is a more substantial and pervasive form of change that includes the change of organisational culture and its political web, must be introduced to ensure their survival.

Since the environment of organisations is ever more complex and dynamic, we argue that a unified model, which encompasses both adaptation and transformation, should be developed and empirically tested with the aim of better representing and understanding change in organisations.

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