Complex adaptive systems as a theoretical tool in urban planning

Verna Nel

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"Like the standing wave in front of a fast moving stream, a city is a pattern in time. No single constituent remains in place, but the city persists."

John Holland (1995: 1)

Abstract

If systems comprise interrelated parts that interact and mutually influence one another, then a city can be considered a system. This article argues that cities are complex adaptive systems comprising of numerous components and subsystems that through their interactions create novel behaviours including high levels of self organisation. This view of the city as system differs from the so-called systems view of planning which viewed cities as relatively simple systems that can be controlled. As complex adaptive systems cities are able to respond to their environments demonstrating emergent behaviour that is an attribute of the system as a whole. Examples of other complex adaptive systems provide lessons for city development such as the need for constant growth and change if stagnation and death are to be avoided. As too much control can stifle the growth of complexity, the emphasis should rather be creating the appropriate rules and enabling community involvement.

KOMPLEKSE AANPASSING SISTEME AS TEORETIESE HULPMIDDEL TOT STADSBEPLANNING

Indien sisteme uit interafhanklike onderdele bestaan wat mekaar wedersyds beïnvloed, dan kan 'n stad as 'n sisteem beskou word. Hierdie artikel stel voor dat stede komplekse aanpassingsisteme is, bestaande uit talle elemente en subsisteme wat deur middel van hul interaksies nuwe gedrag skep insluitend hoë vlakke van self-organisasie. Hierdie beskouing van die stad as sisteem verskil van die sisteembenadering wat stede beskou het as relatiewe eenvoudige stelsels wat beheer kon word. Stede, as komplekse aanpassingsisteme kan op hul omgewings reageer en veranderende gedrag toon, 'n eienskap van die sisteem as geheel. Voorbeelde van ander komplekse aanpassingsisteme stel beginsels vir stedelike ontwikkeling, soos die belangrikheid van konstante groei en verandering indien hul stagnasie en die dood wil vermy. Die ontwikkeling van kompleksiteit kan beperk word deur te veel beheer, daarom behoort die klem eerder op die daarstelling van toepaslike reëls en gemeenskapsbetrokkenheid te wees.

DITSELA TSA DIBAKA TSA BOITLWAETSO E LE SESEBEDISWA NAKONG EO HO RALLWANG METSE YA DITOROPO KA YONA.

Haeba ditsela tsena di na le dikarolo tse sebedisanang, tse sebedisanang ha mmoho le ho tshwaetsana ka katamelano, ka mokgwa o jwalo motsesetoropo o ka tadingwa e le mokgwa kapa tsela. Pampiri ena e hlahisa hore metse ya ditoropo ke ditsela tsa dibaka tsa bokitlwaetso e nang le dintho tse ngata ka hara yona le ditselana tse nyenyane tseo ka mekgwa e metjha ya tshebedisano ho kenyeletsa le maemo a phahameng a boitlhophiso. Tjhadimo ena ya motse wa setoropo e le tsela e fapaneng le seo ho thweng ke ditsela tsa tjhadimo tsa moralo tse tadimang metse lya ditoropo e le ditselana (ditsamaiso) feela tse ke keng tsa laolwa. Metse ya ditoropo jwalo ka ditsela tsa dibaka tsa boitlwaetso e kgona ho arabela ditikolohong tsa tsona di bontsha tsela e ntjha eo e leng letshwao la tsamaiso yohle. Mehlala ya ditsamaiso tsa dibaka tsa boitlwaetso di fana ka dithuto bakeng sa ntshetsopele ya motse wa setoropo e leng ntho e kang tlhoko ya kgolo le phetoho haeba ho tlameha hore ho thibelwe ho ema nnqa e le nngwe le lona lefu. Ereka ha taelo e senyekgenyekge e ka thibela kgolo ya dibaka, toboketso e mpe e be yona e etse kapa e bope melao e nepahetseng esita le ho kgontsha ho hore baahi (setjhaba) ba be le hona ho ikakgela ka setotswana.

Prof. Verna Nel, Head, Dept. of Urban and Regional Planning, University of the Free State, P.O. Box 339, Bloemfontein, 9300, South Africa. Phone: +27 (0)51 401 2486, email: <nelvj@ufs.ac.za>

1. INTRODUCTION

Cities have often been described as systems; both Geddes – one of the founders of urban planning - and later McLoughlin wrote of cities in terms of living systems (Taylor 1998: 62). However, despite this analogy, city planning as practised in South Africa has largely been reductionist, dismembering the components or subsystems and analysing them in detail, as has been the case with much Western science (Innes & Booher, 1999: 146; Celliers,1998; Nel & Serfontein, 2002; Batty, Barros & Junior, 2004: 2). Planning and analysis have been sector or land-use based; only recently have the concepts of integrated planning come to the fore (Harrison, 2006; Oranje & van Huyssteen, 2007). While this reductionist approach has been very successful in many fields, it cannot explain complex behaviours that arise from the interaction of the components of the system. Such systems must be viewed holistically, with equal emphasis on the constituents of the system and their mutual influences. Chaos and complexity theories have arisen from studies of systems where the focus has been on the dynamics of the system, the patterns that emerge, and the role of the components or agents.

This article argues that the theories and concepts related to complex adaptive systems offer useful insights in understanding and responding to the challenges of modern cities. The value of complex adaptive systems thinking is being recognised in the physical and biological sciences as well as in economics, business management and social sciences (Sanders, 1998; Halmi, 2003; Levin, 1998; Sawyer, 2002; McCann & Selsky, 1984; Chaffee & McNeill, 2007). There is furthermore, a small, but growing body of literature that refers to chaos and complexity theory from a planning perspective (Cartwright, 1991; Innes & Booher, 1999), often using mathematical modelling and geographic information systems (Torrens, 2000; Batty *et al*., 2004, Webster & Wu, 2001).

Allmendinger (2002: 52) points out that a complex adaptive systems approach contrasts with the systems planning approach of the 1960s and 1970s in that the latter were viewed as simple and predictable enabling centralised decision-making and authority, whereas a complex adaptive systems approach recognises the complexity of the city, that the systems are not reducible and diffusion of power is necessary.

The systems planning approach was largely derived from the new science of cybernetics (the study of communication and control of regulatory systems). While acknowledging that cities are not static, but comprise systems with social and economic components, the approach was to analyse the various subsystems, and attempt to model their behaviour[1] and then control it (Taylor, 1998; Allmendinger, 2002; Hall, 2002a). This approach with its focus on control, has been criticised on the grounds of being static, pseudo-scientific and technocratic and that it did not "appreciate the complexity of the competing objectives and conflictual objectives of the growing multitude of actors involved" (Allmendinger, 2002: 50). In response to the criticisms planning has acknowledged that it is not value-free, and has embraced community participation and pro-poor approaches. However, the concept of a city as system of interrelated components and subsystems is still valid and valuable.

2. COMPLEX ADAPTIVE SYSTEMS

The theory of complex adaptive systems has developed from research in a number of fields ranging from evolutionary biology (Kauffman, 1995) to economics (Arthur, 2005; Kochugovindan & Vriend, 1998). Among the first systems to be investigated were chaotic systems, exhibiting turbulence (Gleick, 1998) and later, supported by the work of the Santa Fe Institute (Waldorf, 1992), the concept of complex adaptive systems developed.

A complex adaptive system is firstly a system, namely an entity that maintains its existence and its function through the interaction of its parts (O'Conner & MacDermott, 1997: 254). As it is these interactions that define the system, it cannot be broken down into its constituent parts. It is not the number of elements but the nature of the interactions that determine the richness of a system (Celliers, 1998: 3-10). Just as 22 amino acids form the basis for numerous proteins and millions of books have been written using the 26 letters of the English alphabet, so the unique use or recombination of the components of a system enables aggregation, generalisation, diversity and novelty. Interaction and feedback are among the most critical features of a system.

Complex adaptive systems share some characteristics with simpler systems such as chaotic systems. The latter are essentially non-linear deterministic systems, implying that, while they may be governed by rigid, predetermined or simple laws, their behaviour is unpredictable (stochastic) on a local level, while acting within certain parameters known as an attractor (Cohen & Stewart, 1994: 20; Gleick, 1998: 306). Generally these systems are dissipative, requiring continuous inputs of energy. Water draining from a bathtub in a stable vortex represents such a chaotic system where gravitation provides the energy.

Non-linear systems demonstrate extreme sensitivity to initial conditions; small changes may be amplified throughout the system, or it can demonstrate strong oscillations or the stability of a standing wave (Gell-Mann, 1994: 25; Holland, 1995). However, small perturbations can also be dampened so that the system returns to its former or a very similar trajectory. The so-called 'butterfly effect', an extreme sensitivity to initial conditions where the flap of a butterfly's wing in one part of the world could cause a hurricane in another, epitomises the ripple effect of small changes in one area on the remainder of the system (Lewin, 1995: 11; Holbrook, 2003: 11).

Many chaotic systems exhibit a greater or lesser degree of self-organisation where unplanned and unexpected patterns spontaneously emerge. These systems appear to indicate global patterns of cooperation (Davies, 1989: 73). Examples include chemical reactions (Davies, 1989: 85-87; Goodwin, 1994: 41-45), fireflies flashing rhythmically (Strogatz, 2003: 13), flocking of birds or schooling of fish, and the formation of galaxies and stars (Morowitz, 2002: 26). It was, however, the study of weather patterns that produced one of the first papers in complexity studies (Stewart, 1997: 121).

Besides the phenomenon of self organisation, many complex adaptive systems exist in a critical state, that is, a state that occurs on the brink of a phase transition, where the state of the system is poised between two alternatives or two attractors (Ball, 2004: 110, 298). A small perturbation can nudge the system into one or another attractor. Self-organised criticality refers to the ability of a system to return to a previous critical state after a disturbance (Ball, 2004: 298; Ward, 2001: 86). An attractor is a stable or equilibrium point – often a lowest energy point – to which a system converges. While there may be minor variations, these attractors are generally contained within the phase space giving the impression of little change externally (Rihani & Geyer, 2001: 240).

Attractors vary from point attractors (also known as a sink) which is common in linear systems, limit cycles (a closed loop, indicating a periodic trajectory) to strange attractors (Stewart, 1997: 86-92; Gribbin, 2004: 81, 82). The latter represents a non-periodic (aperiodic), non-repeating trajectory that remains within a finite phase space and has a non-integer or fractal dimension. Besides having non-integer dimensions, fractals also exhibit self-similarity at all scales (Ward, 2001: 78-81; Buchanan, 2002: 99). This implies that a view at one scale will be similar at any other scale or, in the words of Strogatz (2003: 255) "when an arbitrarily small piece of a complex shape is a microcosm of the whole." Examples include clouds, drainage basins and the branching of blood vessels.

Complex adaptive systems display many traits of a complex or chaotic system. They comprise interrelated components (meaning they are systems), but these change and develop over time while retaining coherence (Holland, 1995: 58). The whole is far greater than the sum of the individual components. Critically, these systems respond with modifications to changes in their environment (for example a bacterium reacting to changes in the density of food sources or a hibernating animal responding to the onset of winter). Such changes are evident in the global system and may be slow or sudden as the system moves from one attractor to another (Ball, 2004: 128-133). However, changes to the components of the system may not necessarily translate into dramatic changes in the system, as in the case of an organ such as the liver which continues to function despite the continuous death of its individual cells.

1 Systems planning introduced the concept of planning as a process rather than a product (Hall, 2002b) as well as the use of computer models and techniques as planning tools.

Emergence is a fundamental characteristic of complex systems and refers to the novel manner in which a system can behave that cannot be reduced to the behaviour of component parts or systems (Morowitz, 2002: 13, 14). Buchanan (2002:198) defines emergence as "the idea that meaningful order can emerge all on its own in complex systems of many interacting parts." For Holland (1998: 7) emergence pertains to persisting patterns despite the turnover of the constituents thereof. Hierarchies are also a feature of complex systems, arising spontaneously in the self-organising process.

Levin (2002: 4) defines complex adaptive systems in terms of diverse components that interact locally and a separate process that selects some of the components for enhancement or replication.

Holland (1995: 11- 40) and Celliers (1998: 3-10) include other aspects in their descriptions of complex adaptive systems. One of these is the ubiquity of flows (the economic multiplier effect that traces the cumulative impact of certain activities in an economy is one example of a flow). Complex adaptive systems are open systems, interacting with their environment and demanding a constant flow of energy and are thus far from equilibrium (equilibrium is equated with death). The interactions tend, however, to blur the boundaries between systems. As complex adaptive systems evolve their history is important in understanding their present. Also individual agents within the system may come and go, but their role or function may be replaced by a somewhat different kind of agent (such as taxis replacing horse-drawn hackney cabs).

These descriptions emphasises the structure of interactions, non-linearity and openness to the environment. Feedback loops can amplify or dissipate the effect of perturbations, the former moving the system to another state while the latter ensures stability. Self organisation that arises spontaneously from the interaction of the components or agents is a defining characteristic of complex adaptive systems. Therefore, there need not be any central control to enable the system to function and respond to its environment.

3. CITIES AS COMPLEX ADAPTIVE SYSTEMS

Cities are not only complex, dynamic, non-linear systems, but they are responsive to internal and external changes and thus, as will be demonstrated below, have the attributes of a complex adaptive system.

Cities are dissipative systems, demanding a constant inflow of resources to permit their functioning (Reader 2004: 301). These resources range from basics such as water and food, to economic goods and information. Cut off these supplies to a modern city and it will rapidly collapse. A power failure in 1996 brought several cities in America to a halt, without power for public transport (electric trains and the underground transport systems), lighting and no means of preserving food (Strogatz, 2003: 230).

Hierarchies are prevalent within cities. There are hierarchies of functions (for example retail) and of systems that nestle within systems (such as transport).

Cities are sensitive to initial conditions. This can be reflected in their morphology (Johnson, 2001: 36-38; Morris, 1994) as well as the manner in which they develop their economies. Some small initial factor such as a particular industry or development can determine the city's trajectory in a unique and non-replicable manner. Land use patterns, often spontaneously arising from local demand tend to persist, despite changing modes of production and transportation.

Modern cities tend to live on the edge of chaos, maintaining a perpetual balancing act between the benefits of the agglomeration and potential disasters such as epidemics of disease, terrorism and disruptions of the supplies on which the cities rely. Cities, however, remain resilient. They have survived changing technologies that influenced their economies, natural disasters, war and terrorist attacks (Vale & Campanella, 2005: 3). Batty et al., (2004: 3, 9) have investigated such resilience along with concepts of transformation and emergence. While the agents – citizens, communities, specific industries - may change over time, the city continues. New technologies may change local industries, or the manner in which the city connects, but it does not change the city as a whole.

Cities also display several other signatures of complexity such as fractal dimensions and self-similarity across scales (Torrens, 2000: 9, 31; Batty *et al*., 2004: 5). Self-similarity is evident in a multi-nodal city with its central business district, regional centres and local centres.

Complex adaptive systems have high levels of self organisation, and so does the city. These are most evident in settlements where there is little central control yet the settlements function effectively or in urban economies that are largely unregulated.

4. MODELS OF COMPLEXITY

This section will present four explorations into the world of complex adaptive systems' computer modelling exercises that were developed in different fields, but which tell similar stories (see Table 1). These include a population model from evolutionary biology, a model based Boolean networks and one using cellular automata. The section concludes with a brief description of a different type of simulation, the artificial society 'Sugarscape' and its implications for societies.

4.1 Population Model

The application discussed below is based on a simplified version of a population model developed by Robert May, a biologist who was testing a population growth model based on non-linear logistic equations (Gleick, 1998: 69-80; Ward, 2001: 255, 256; Gribbin, 2004: 75). In this model, the growth rate (a function of births and deaths) determines the welfare of the population. If this growth rate is too low the population dies out as it is not able to replenish itself. When the growth parameter is greater than one but less than three, the population will, despite some initial oscillations, converge on a steady state, neither growing nor declining. However, once the population exceeds another threshold where the parameter is approximately 3.566 chaos sets in with the population fluctuating wildly over ever shortening periods. At the cusp of the stable and the chaotic regions– 'the edge of chaos' - is a region of relative stability yet displaying change and growth. It is neither static nor chaotic, but demonstrates many of the traits of complexity and emergence (Goodwin, 1994: 169; Gleick,1998: 71).

4.2 Networks

A different model, developed by Stuart Kauffman based on Boolean networks (Gribbin 2004: 163-171; Kauffmann, 1995), also identifies a region on the 'edge of chaos' as the most interesting part of the model. This model can be likened to an array of light bulbs (nodes) connected to each other. When the number of connections is low the network will generally follow a short cycle or freeze into a stable configuration. When the number of connections to each node is greater than two, the system moves rapidly between one attractor (groups of the same lit bulbs) and another: it is now in a chaotic state. "Sparsely connected networks exhibit internal order; densely connected ones veer into chaos; and networks with a single connection element freeze into mindlessly dull behaviour" (Kauffmann, 1995: 85).

Only when there are exactly two connections per node is the system both stable and interesting. This state is analogous to the stable but dynamic 'edge of chaos' state in the above-mentioned population model. Again, there are powerful attractors to which the system rapidly converges.

Strogatz and Watts (Strogatz, 2003: 241-244); also investigated networks and how the level of random wiring or degree of connectedness influences their structure and function. The most interesting networks were those about halfway between rigidly ordered and completely random (Ball, 2004: 458-463; Buchanan, 2002: 132). Furthermore, their work noted that for information to spread, all that is required are some random links between groups (clusters). These links connect the individual tight clusters enabling the entire network to demonstrate emergent behaviour.

Depending on the architecture of the network, certain nodes or hubs can assume dominance and thus become the most sensitive to attack (Ball, 2004:489), due to their high connectivity to other nodes. Damage to these will have consequences for much of the remaining system. This has implications for food chains where the removal of key species can have a catastrophic effect on the food web (Buchanan, 2002: 153) or internet servers where the loss of key 'hubs' can disastrously affect its functionality. Road networks can also share these properties with an accident on a critical portion of a freeway impacting on large portions of an entire city's traffic flow.

4.3 Cellular Automata

Similar classes of behaviour to those in the above-mentioned models were identified by Wolfram in his study of cellular automata (Torrens, 2000: 20; Coveney & Highfield 1995). Regardless of the specific local rules employed, four classes of behaviour emerged: "Class I, in which the pattern disappears with time or becomes a fixed, static, or homogenous state; Class II, in which the pattern evolves to a fixed, finite size, forming structures that repeat indefinitely; Class III, which yield so-called chaotic states (i.e. structures that never repeat) with little semblance to of regularity; and Class IV, in which complex patterns grow and contract irregularly" (Coveney & Highfield, 1995: 99). According to Torrens (2000: 26) the cellular automaton space can be equivalent to an environment or a landscape and can represent urban spatial structures, land uses and densities.

From the above it is clear that, despite the differences in subject matter, similar patterns emerge in these models as illustrated in Table 1 below. Little activity or connections leads to 'death' be it extinction or cessation of activity. Moderate activity results in a dull stability or stasis, while high activity causes chaos. There is, however, a state between dull stability and chaos that induces relatively stable, dynamic and interesting behaviour. This is 'the edge of chaos' or complexity.

4.4 Sugarscape

The 'Sugarscape' model is essentially a very simplified model of a society. This deterministic model with its surprising emergent behaviour can be used to test theories regarding societal behaviour from the bottom up.

It is an artificial society living in two dimensions of cyberspace living off primarily sugar created by Joshua Epstein and Robert Axtell (Epstein & Axtell, 1996). This computer simulation tests how societies develop based on simple rules. These rules govern how they collect sugar (resources), trade, defend their sugar and generally interact with each other. Although the rules are simple, surprisingly complex behaviour emerges. These include highly skewed wealth distributions, migratory behaviour, spatially segregated tribes, and various conflict modes. It demonstrates the importance of trade and social networks for survival (Epstein & Axtell, 1996: 33, 159). This model demonstrates that "there may be highly interactive and counter-intuitive ways to induce social outcomes from the bottom up." The model demonstrates that events such as extinction can arise endogenously through local interactions alone. "Combinations of small local reforms –'packages' exploiting precisely the nonlinear interconnectedness of things – may result in desirable outcomes in the large" (Epstein & Axtell, 1996: 161).

5. LESSONS FROM THE MODELS

Although the four models presented above examine different phenomena, the patterns that emerge hold lessons for urban planning. Three of the four models depicted very similar states (see table 1). These can be summarised as cessation (State A), stasis (State B), chaos (State C) and complexity (State D). Each of these states can be applied to urban settlements.

State A: Small settlements such as rural villages with a low growth rate tend to stagnate and slowly die. Depopulation of these areas, particularly of economically active persons, results in a skewed

STATE	POPULATION MODEL	NETWORKS	WOLFRAM CELLULAR AUTOMATA	LABEL
A	Low growth: Extinction	Few connections: little activity	Class I: Cessation	Death
B	Moderate growth: Steady state	One connection: steady state	Class II: Steady state	Stasis
C	Rapid growth: Chaos, no order	More than two connections: chaos	Class III: Chaos, no regularity	Chaos
D	Cusp between steady and chaotic states: dynamic stability	Exactly two connections: stable, dynamic patterns	Class IV: Complex patterns	Complexity

Table 1: Comparison between models
Source: Author

population structure with higher than average numbers of the elderly, the very young and female-headed households, circumstances correlated with higher levels of poverty (South Africa, 2006). The lack of local economic opportunity drives the economically active from the settlement, setting in course a vicious circle (a form of feedback).

State B: Settlements that have a limited growth such as rural market centres grow and change very slowly. Little new investment in business is noted, and any new housing is state subsidised housing replacing informal settlements. According to Innes & Booher (1999: 146) such equilibrium systems have limited capacity to adapt to change.

State C: Rapidly growing urban settlements face other problems. Their infrastructure cannot cope with the influx of migrants looking for opportunities, and consequently, shantytowns that lack decent housing, sanitation, water supply and waste removal spring up around the city, often on marginal land. Simultaneously, the informal economy swells to absorb those who cannot find formal employment as evidenced in activities such as hawkers, car washers and sidewalk vehicle repairs

State D occurs where there is a balance between growth and chaos, where there is an opportunity for growth and experimentation and the opportunity to evolve (Innes & Booher: 1999:146). Here the city can absorb growth and responds to opportunities created in novel and unexpected ways. New industries emerge, along with new markets and niches. Additional wealth is generated and employment opportunities abound. New technologies are incorporated into the fabric of the city, changing its face if not its structure. This is the vibrant, dynamic city of potential.

There are clear policy implications for planning emanating from these models, some of which are already reflected in the National Spatial Development Perspective (NSDP) (South Africa, 2006).

State A (dying) settlements require social support (investment in people) rather than major investments in economic development, unless that investment can propel the settlement into another trajectory. Stable State B towns require adequate flows of resources to maintain the level of activity and prevent a decline into State A extinction. Conversely, State C settlements require resources to support the increases in growth and population activity and to create a balance between the growth rate and the absorption rate into the city and economy. State D cities require support, flexibility and freedom to maintain their dynamic balance.

6. OTHER LESSONS FROM COMPLEX ADAPTIVE SYSTEMS

Connectivity is critical. While connectivity within groups is important, it is the links between groups that enable flow of goods and ideas. Batty *et al*., (2004: 8) points out that the level of connectivity must be adequate for the city to function as a whole, but too much connectivity results in redundancy. Is there a lesson here regarding an optimum degree of transport connectivity beyond which chaos and overload will occur? Studies in networks furthermore indicate high connectivity of a network can result in chaos or increased vulnerability (Ball, 2004: 491-495) due to the exponential escalation of feedback that amplifies throughout the links in complex systems. Thus, cities are vulnerable if vital nodes are damaged or removed from the system. These nodes can be critical public transport systems (such as the London Underground after the July 2005 bombings), key utilities, main industries, or a major employer. It may be possible to prevent the crippling effects of damage to such nodes or systems by re-engineering their architecture and links (see Ball, 2004: 468-496) or building in redundancy.

One of the most important lessons is that change is vital and stasis is death. A minimum level of growth and change within a city is essential for survival. This has major implications for the manner in which we manage our cities. A vision of a city as a static orderly place and that focuses on the physical structures emphasises equilibrium, ignores the essential processes that create and maintain the city: the flows and interactions between agents, and thus seeks to control most external aspects of the city, its form, functions (land uses), densities, connectivity (transport modes) and even the aesthetics. However, such control can move a city from vibrant dynamism of State D – the edge of chaos – to the dull stability of State B. Land use management systems must accommodate the unexpected and be flexible to include new uses, unusual bedfellows and a wider range of uses in any one area or zone.

Rooney (2003: 4) criticises current approaches to city development:

> our attempts to change behaviour have been based on a model of directing (or coercing) people by legislation or exhorting people to change without giving them the requisite information or techniques, nor engaging them in developing a shared intent that was congruent with their values and beliefs. In short, we tended to operate from a mechanical model of the world rather than recognising that we are dealing with a complex living adaptive system.

Batty *et al*., (2004: 16) calls for focus on process, not product; and function rather than form, accompanied by an understanding, not only of global forces, but the impacts of local action.

Rather than rigid plans and strict land use management zoning schemes, clear intent, an appropriate framework, consistently and fairly applied that creates sufficient stability for the agents in the city to function effectively is required. The city must avoid stifling order created by rigid rules and imposed by a corrupt or inflexible bureaucracy (Rihani & Geyer, 2001: 243). Innes & Booher (1999: 150) propose three strategies for planning and managing complex areas: developing and using indicators, consensus building and leadership that encourages a common sense of purpose and empowers the community in the process. The strategic choice approach developed by Friend & Hickling (2005) can also be a valuable tool.

Self-organisation is property of complex adaptive systems. Most pre-industrial cities were not formally planned, but developed in response to the needs of the time as have Western economies from pre-industrial craft-based economies to modern industrialisation. The informal settlements and economies of the global South are also emergent responses to the prevailing circumstances. Should these not be accepted as such, and appropriate responses be developed, rather than forcing these into a Western model of city or development?

To enable development the city must create the space for the essential interactions that define the system, through an enabling environment with social, political and financial freedoms. Such freedom must be accompanied by investment in human capital to enable citizens to partake in the economy: not only should they be aware of and understand, but they should be in a position to respond to opportunities. According to Rihani & Geyer (2001: 242) the:

> layer of self organised complexity that lies on the edge of chaos could only emerge if individuals were 'free' to interact and 'capable' of interacting, and if their actions were facilitated by 'appropriate' rules that command popular support."

Moreover, community participation in the process of development, and by implication in planning, is critical (Rihani, 2002: 137). He also advocates a greater emphasis on self help to encourage greater self sufficiency while still providing basic social services (Rihani, 2002: 139).

In acknowledging the informality that pervades the cities of the global South, planners should accept that control is very limited and that their roles will be to facilitate development, through increasing awareness of opportunities, and creating the appropriate rules that encompass basic freedoms yet encourage the emergence of new forms that meet local needs.

7. CONCLUSION

This article has argued that a city is a complex adaptive system constantly evolving in response to local or global changes. It thrives on the interactions of its agents and subsystems. While the agents and subsystems may come and go, the resilient city continues. However, for the city to prosper, as with other complex adaptive systems, a constant inflow of resources, including information and energy is essential, as well as the flexibility and freedom to maintain those flows and interactions. Should the growth rate or rate of interaction fall below a certain minimum, then stasis and decline are inevitable. To maintain the activity or growth rate, the agents (citizens) require an appropriate legal and governance framework, supported by enabling social and economic environment that empowers residents to partake in the system. For planners this implies a move from a control perspective to one that recognises the fluidity of the city. Attention to the processes and flows rather than the products (infrastructure, activity) will alert us to opportunities and threats and enable us to direct the city to a more appropriate trajectory.

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