

# APPENDIX A

## **A GLOSSARY OF URBAN COMPLEXITY**

### **Adaptation**

‘In the theory of Darwinian Evolution, adaptation is the ongoing process by which an organism becomes "fit" to a changing environment.... A fundamental characteristic of complex, adaptive systems is their capacity to adapt by changing the rules of interaction among their component agents. In that way, adaptation consists of "learning" new rules through accumulating new experiences’ (Goldstein, 2001, unpaginated).

### **Adaptive Redevelopment**

‘A redevelopment a plot, a series of plots, within the existing street system without the introduction of new streets’ (Conzen, 1960, pp.69, 95, 123; quoted in Larkham and Jones, 1991, p.13).

### **Agents of Change**

‘Agent; Agent of change; Amenity group; Applicant; Builder; Consultant; Depositor; Developer; Developer agent; Estate agent; Initiator; Institution; Original rural landholder; Owner; Planner/planning officer; Speculator/speculative developer; Subdivider’ (Larkham and Jones, 1991, p.10).

### **Agent-Based Models**

‘Systems composed of individuals who act purposely in making locational/spatial decisions’ (Batty, 2008, p.2).

### **Attractors**

- (1) ‘The idea of attractor deals with “phase/state/condition space”. In the development of a dynamical system over time we have attractors if the systems’ trajectory does not move through all the possible parts of an  $n+1$  (the  $+1$  representing time) state space, but instead occupies a restricted part of it’ (Byrne, 1998, p.168).

(2) ‘The evolution of a nonlinear, dynamical, complex system can be marked by a series of phases, each of which constrains the behaviour of the system to be in consonance with a reigning attractor(s)... The dynamics of the system as well as current conditions determine the system’s attractors. When attractors change, the behaviour in the system changes because it is operating under a different set of governing principles. The change of attractors is called bifurcation, and is brought about from far-from-equilibrium conditions which can be considered as a change in parameter values toward a critical threshold’ (Goldstein, 2001, unpaginated).

### **Bifurcation**

(1) ‘A process whereby divergent paths are generated in a trajectory of change in an urban system’ (Batty, 2008, p.2).

(2) ‘The emergence of a new attractor(s) in a dynamical, complex system that occurs when some parameter reaches a critical level (a far-from-equilibrium condition). For example in the logistic equation or map system, bifurcation and the emergence of new attractors take place when the parameter representing birth/death rates in a population reaches a critical value. More generally, a bifurcation is when a system shows an abrupt change in typical behaviour or functioning that lasts over time’ (Goldstein, 2001, unpaginated; see also Chapter Three, figures 3.6, 3.7, and 3.8).

### **Building Adaptation**

‘This is a particularly wide-ranging category, much subdivided, covering all changes to the building fabric rather than new building/major rebuilding/redevelopment’ (Larkham and Jones, 1991, p.23).

### **Building Pattern**

‘In town-plan analysis, “this is the arrangement of existing buildings, *i.e.* their block-plans in a built-up area viewed as a separate element complex of the town plan’ (Conzen, 1969, p.123; quoted in Larkham and Jones, 1991, p.24).

### **Butterfly Effect**

‘A popular image portraying the property of sensitive dependence on initial conditions in chaotic systems, *i.e.*, a small change having a huge impact like a butterfly flapping its wings in South America eventually leading to a thunderstorm in North America... The Butterfly Effect introduces a great amount of unpredictability into a system since one can never have perfect accuracy in determining those present conditions which may be amplified and lead to a drastically different outcome than expected. However, since chaotic attractors are not random but operate within a circumscribed region of phase or state space, there still exists a certain amount of predictability associated with chaotic systems. Thus, a particular state of the weather may be unpredictable more than a few days in advance; nevertheless, climate and season reduce the range of possible states of the weather, thereby, adding some degree of predictability even into chaotic systems’ (Goldstein, 2001, unpaginated; see Chapter Three, sections 3.1.1.3 and 3.2.2.5).

### **Chaos**

‘A type of system behaviour appearing random-like, yet is actually deterministic and is constituted by a "hidden" order or pattern. Chaos can be found in certain nonlinear dynamical systems when control parameters surpass certain critical levels. The emergence of chaos suggests that simple rules can lead to complex results. Such systems are constituted by nonlinear,

interactive, feedback types of relationships among the variables, components, or processes in the system' (Goldstein, 2001, unpaginated; see Chapter Three, section 3.1).

### **City Size Distribution**

'A set of cities by size, usually population, often in rank order' (Batty, 2008, p.2).

### **Deterministic system**

'A dynamic is determinist if knowledge of it and of the initial state of a system is all we need to know to predict the future of the system. Note that this is a matter in principle. In chaotic determinism we cannot know the initial state of the system with sufficient precision to predict its future trajectory' (Byrne, 1998, p.171).

### **Element Complex/Form Complex**

'The totality of plan elements of one particular kind in a town plan viewed separately from others. There are three element complexes, *i.e.* the street system, the plot pattern and the building pattern' (Conzen, 1969, p.125; quoted in Larkham and Jones, 1991, p.37).

### **Emergent Patterns/ Emergent Properties**

'The arising of new, unexpected structures, patterns, processes, [or properties] in a self-organizing system' (Goldstein, 2001, unpaginated). For instance, in the case of a city system, 'land uses or economic activities which follow some spatial order' (Batty, 2008, p.2).

### **Entropy**

'The concept of Entropy refers to the tendency of things to move toward greater disorder, or disorganization rather than maintaining order. It refers

to the importance of having an open system to import energy, information and materials, which can be used to offset the tendency toward disorganization. The second law of thermodynamics describes the Entropy. The law states that heat dissipates from a central source and the energy becomes degraded, although total energy remains constant' (Flood, 1993, p.12).

### **Entropy Maximizing**

'The process of generating a spatial model by maximizing a measure of system complexity subject to constraints' (Batty, 2008, p.2).

### **Equilibrium**

'A state of the urban system which is balanced and unchanging' (Batty, 2008, p.2).

### **Exponential Growth**

'The process whereby an activity changes through positive feedback on itself' (Batty, 2008, p.2).

### **Far-from-equilibrium**

'The term used by the Prigogine School for those conditions leading to self- organization and the emergence of dissipative structures. Far-from-equilibrium conditions move the system away from its equilibrium state, activating the nonlinearity inherent in the system. Far-from-equilibrium conditions are another way of talking about the changes in the values of parameters leading-up to a bifurcation and the emergence of new attractor(s) in a dynamical system. Furthermore, to some extent, far-from-equilibrium conditions are similar to "edge of chaos" in cellular automata' (Prigogine and Stengers, 1984; quoted in Goldstein, 2001, unpaginated).

### **Fast Dynamics**

‘A process of frequent movement between locations, often daily’ (Batty, 2008, p.2).

### **Feedback**

(1) ‘The process whereby a system variable influences another variable, either positively or negatively’ (Batty, 2008, p.2).

(2) ‘The mutually reciprocal effect of one system or subsystem on another.

Negative feedback is when two subsystems act to dampen the output of the other.... Positive feedback means that two subsystems are amplifying each other’s outputs’ (Goldstein, 2001; see Chapter Three, section 3.2.2.4).

### **Fractal Structure**

‘A pattern or arrangement of system elements that are self-similar at different spatial scales’ (Batty, 2008, p.2; see Chapter Three, section 3.3).

### **Fractal Dimension**

‘A non-integer measure of the irregularity or complexity of a system. Knowing the fractal dimension helps to determine the degree of complexity and pinpoint the number of variables that are key to determining the dynamics of the system’ (Goldstein, 2001, unpaginated; see Chapter Three, section 3.3.2).

### **Geometrical Analysis**

‘Analysis of plots, particularly medieval burgages, with especial reference to relative proportions of width and length’ (Slater, 1990a, pp.74-77; quoted in Larkham and Jones, 1991, p.43).

### **Grid Plan/Gridiron Layout**

‘A rectilinear layout of streets and street blocks. It has been the mark of the founded town since ancient times, producing an efficient circulation

system, and distribution of equal rectangular plots' (Larkham and Jones, 1991, p.44).

### **Initial Conditions**

'The state of a system at the beginning of a period of observing or measuring it' (Goldstein, 2001, unpaginated).

### **Initiator**

- (1) 'This is a popular term used to describe the person or organization upon whose behalf a fabric change is initiated' Larkham and Jones, 1991, p.46).
- (2) The initial step/level from which a fractal shape is constructed (Peitgen *et al*, 2004, p.89; see also Chapter Three, section 3.3.2).

### **Interaction**

- (1) 'The mutual effect of components or subsystems or systems on each other. This interaction can be thought of as feedback between the components as there is a reciprocal influence' (Kauffman, 1993; quoted in Goldstein, 2001, unpaginated).
- (2) In a complex system, '... the effect of two or more variable causes acting together is not simply the some of their effects taken separately. Instead, we find that there are complex emergent properties' (Byrne, 1998, p.173).

### **Land Use Transport Model**

'A model linking urban activities to transport interactions' (Batty, 2008, p.2).

### **Life Cycle Effects**

'Changes in spatial location which are motivated by aging of urban activities and populations' (Batty, 2008, p.2).

### **Linear System**

'A linear system is one in which small changes result in small effects, and large changes in large effects. In a linear system, the components are



isolated and non-interactive. Real linear systems are rare in nature since living organisms and their components are not isolated and do interact' (Goldstein, 2001, unpaginated).

### **Local Neighbourhood**

'The space immediately around a zone or cell' (Batty, 2008, p.2).

### **Logistic Equation**

'An equation that has been applied to various natural systems such as the changes in a system's population over time which show a convergence to some fixed value or values over time' (Goldstein, 2001; see also Chapter Three, equation 3.2).

### **Logistic Growth**

'Exponential growth capacitated so that some density limit is not exceeded' (Batty, 2008, p.2).

### **Lognormal Distribution**

'A distribution which has fat and long tails which is normal when examined on a logarithmic scale' (Batty, 2008, p.2).

### **Micro simulation**

'The process of generating synthetic populations from data which is collated from several sources' (Batty, 2008, p.2).

### **Model Validation**

'The process of calibrating and testing a model against data so that its goodness of fit is optimized' (Batty, 2008, p.2).

### **Morphological Processes**

'The set of process shaping urban form. These include adaptive, additive, repletive and transformative processes' (Larkham and Jones, 1991, p.55).

### **Multipliers**

‘Relationships which embody n’th order effects of one variable on another’  
(Batty, 2008, p.2).

### **Network Scaling**

‘The in-degrees and out-degrees of a graph whose nodal link volumes follow a power law’ (Batty, 2008, p.2).

### **Nonlinear System**

‘A system in which small changes can result in large effects, and large changes in small effects. Thus, sensitive dependence on initial conditions in chaotic systems illustrates the extreme nonlinearity of these systems’  
(Goldstein, 2001, unpaginated).

### **Phase Space/State Space/Condition Space**

- (1) ‘An abstract mathematical space which is used to display time series data of the measurements of a system’ (Goldstein, 2001, unpaginated).
- (2) ‘If there are n variables, there will be n dimensions. The state space of the system at any instant can be describe by its co-ordinates in this n dimensional space with the measured value for each variable aspect being the co-ordinate for that dimension’ (Byrne, 1998, p.173).

### **Plot Pattern**

‘The arrangement of plots – considered separately from the other plan elements – up to the level of street blocks’ (Larkham and Jones, 1991, p.65).

### **Population Density Profile**

‘A distribution of populations which typically follows an exponential profile when arrayed against distance from some nodal point’ (Batty, 2008, p.2).

### **Power Laws**

- (1) 'Scaling laws that order a set of objects according to their size raised to some power' (Batty, 2008, p.2).
- (2) 'A type of mathematical pattern in which the frequency of an occurrence of a given size is inversely proportionate to some power (or exponent) of its size' (Bak, 1996; quoted in Goldstein, 2001, unpaginated; see also Yanguang and Yixing, 2004).

### **Rank Size Rule**

'A power law that rank orders a set of objects' (Batty, 2008, p.2).

### **Reaction-Diffusion**

'The process of generating changes as a consequence of a reaction to an existing state and interactions between states' (Batty, 2008, p.2).

### **Residential Density/Housing Density**

'The number of houses per unit of land including the plots and all streets providing direct access to them. The term applied to an individual plot as well as to a plan unit. In the latter case, it is an average value' (Conzen, 1969, pp.129-130; quoted in Larkham and Jones, 1991, p.70).

### **Scale/Scaling Law**

'The level at which a system is observed. For example, one can observe the coast of England from a satellite or from a jet liner or from a low flying plane, or from walking along the coast, or from peering down into the sand and rock of a cove beach you are standing on. Each of these perspectives is of a different scale of the actual coast of England. Fractals are geometric patterns that are self-similar on different scales' (Kaye, 1989; quoted in Goldstein, 2001, unpaginated).

### **Scale-free Networks**

‘Networks whose nodal volumes follow a power law’ (Batty, 2008, p.3).

### **Segregation Model**

‘A model which generates extreme global segregation from weak assumptions about local segregation’ (Batty, 2008, p.3).

### **Self-organisation**

‘A process in a complex system whereby new emergent structures, patterns, and properties arise without being externally imposed on the system. Not controlled by a centralized, hierarchical "command and control" centre, self-organization is usually distributed throughout a system’ (Goldstein, 2001, unpaginated).

### **Self-organized Criticality (SOC)**

‘... a phenomena of sudden change in physical systems in which they evolve naturally to a critical state at which abrupt changes can occur. That is, when these systems are not in a critical state, i.e., they are characterized by instability, output follows from input in a linear fashion, but when in the critical state, systems characterized by self-organized criticality act like nonlinear amplifiers, similar to but not as extreme as the exponential increase in chaos due to sensitive dependence on initial conditions’ (Bak, 1996; Waldrop, 1992; quoted in Goldstein, 2001, unpaginated).

### **Simulation**

‘The process of generating locational distributions according to a series of sub-model equations or rules’ (Batty, 2008, p.3).

### **Slow Dynamics**

‘Changes in the urban system that take place over years or decades’ (Batty, 2008, p.3).

### **Social Physics**

‘The application of classical physical principles involving distance, force and mass to social situations, particularly to cities and their transport’ (Batty, 2008, p.3).

### **Spatial Interaction**

‘The movement of activities between different locations ranging from traffic distributions to migration patterns’ (Batty, 2008, p.3).

### **Strange Attractor**

‘An attractor of a chaotic system which is bound within a circumscribed region of phase space yet is aperiodic, meaning the exact behaviour in the system never repeats. The structure of a strange attractor is fractal.... A strange attractor portrays the characteristic of sensitive dependence on initial conditions (the Butterfly Effect) found in chaos’ (Goldstein, 2001, unpaginated).

### **Trip Distribution**

‘The pattern of movement relating to trips made by the population, usually from home to work but also to other activities such as shopping’ (Batty, 2008, p.3).

### **Urban Hierarchy**

‘A set of entities physically or spatially scaled in terms of their size and areal extent’ (Batty, 2008, p.3).

### **Urban Morphogenesis**

‘The creation of physical forms viewed as a developmental or evolutionary process’ (Whitehand, 1981, pp.1-24; quoted in Larkham and Jones, 1991, p.54).

### **Urban Morphology**

(1) ‘Patterns of urban structure based on the way activities are ordered with respect to their locations’ (Batty, 2008, p.3).

(2) 'The study of the physical (or built) fabric of urban form, and the people and processes shaping it' (Larkham and Jones, 1991, p.55).

**Urban System**

'A city represented as a set of interacting subsystems or their elements' (Batty, 2008, p.3).