2-2016

Considering how morphological traits of urban fabric create affordances for complex adaptation and emergence

Sharon Wohl
Iowa State University, swohl@iastate.edu

Considering how morphological traits of urban fabric create affordances for complex adaptation and emergence

Abstract
This paper examines how physical and material properties of the urban fabric help enable the evolution of programmatically coherent spatial districts. It considers how contingent and non-linear processes intertwine to manifest in the unfolding of distinct sites and territories. Drawing concepts and terminology from both evolutionary economic geography and the sciences of complexity, it emphasizes how physically situated morphological traits help underpin urban processes of self-organization and emergence.

Keywords
Complexity, Emergence, Evolutionary economics; Phase space; Self-organization

Disciplines
Architecture | Human Geography

Comments
This is the accepted manuscript of an article published in *Progress in Human Geography* 40, no. 1 (2016): 30–47, doi:10.1177/0309132514566344. Posted with permission.

Considering how morphological traits of urban fabric create affordances for Complex Adaptation and Emergence

Sharon Wohl, *Iowa State University; Delft Technical University*

Abstract
This paper examines how physical and material properties of the urban fabric help enable the evolution of programmatically coherent spatial districts. It considers how contingent and non-linear processes intertwine to manifest in the unfolding of distinct sites and territories. Drawing concepts and terminology from both evolutionary economic geography and the sciences of complexity, it emphasizes how physically situated morphological traits help underpin urban processes of self-organization and emergence.

Keywords
complexity, self-organization, evolutionary economics, emergence, phase space

This is the accepted manuscript of an article published in *Progress in Human Geography* 40, no. 1 (2016): 30–47, doi:10.1177/0309132514566344.

A. Introduction

I. Context:
Geographers employing relational approaches to understanding space consider how non-fixed, non-territorial and non-linear global forces generate dynamics which in turn inform locally situated spatial environments (for general reviews see Yeung (2005); Massey (1999), Urry (2003) and Amin (2002, 2004)). This approach considers space to be primarily constituted through relational attributes - pertaining to flows and processes - rather than Euclidean formulations that trace objects and boundaries (Delanda (2005), Urry (2005)).

Concurrent with this move away from Euclidean, containerized spatial constructs, an emerging branch of economic theory, Evolutionary Economic Geography (EEG) is deriving complementary insights into ways that economic spaces might be relationally conceived. EEG examines how globally situated social, technological and economic processes impact upon the unfolding of localized economic environments. It shares many aspects of relational ontology - breaking from 'equilibrium' modes upon which classical economic theories were based - to instead consider relational, non-linear and contingent spaces (Beinhocker, 2007). In this conception, the spatial organization of economic activities is understood as a manifestation of historic, dynamic and path dependent relations of socio-economic flows (Boschma & Frenken, 2011). EEG considers how a better understanding latent territorial capacities might help spur more effective economic development (Lambooy & Boschma, 2001). Here, policy could involve tuning local firm capacities such that they are better able to gather and leverage ‘the complex nexus of relations’ (Yeung, 2005: 37) that are the subject of relational discussions.

EEG thus pays attention to *localized* features of institutional settings - and/or the actors therein - examining how these are responsive to relational dynamics. This focus upon local specificity, while not negating the global and fluid dimensions of relational thought, instead considers how flows come to be sedimentized in specific geographical locations (which Urry (2003) describes as ‘moorings’). These instances of sedimentation are themselves understood as being subject to circumstantial historical conditions - that are contextual, path-dependent and contingent (Bathelt & Glückler, 2003) - and which might equally have manifested in entirely different trajectories.

In order to better grasp this notion of multiple potential trajectories of spatial unfolding, Martin Jones (2009), develops the notion of *Phase space* (citing both Prigogine & Stengers (1984), and Richards (2004); (who in turn references Melton, (1958)). The concept of phase space has its origins within the physical sciences, where it refers to potential trajectories of complex systems. It ‘contains not just what happens but what might happen under different circumstances’ (Jones, quoted in Harrison, Massey & Richards, 2006: 468). The potentialities of phase space correspond with a system’s ‘degrees of freedom’, where multiple trajectories exist as possible futures. These trajectories can be thought of as clusters or ensembles of points, where the density of points relates to the statistical probability of a particular trajectory being manifested (see Prigogine & Stengers, 1984: 247). In applying this concept to geography, Jones describes phase space as, ‘captur[ing] all the possible spaces in which a spatio-temporal system might exist in theoretical terms’ (Jones, 2009: 23).

When geographers consider territorial actualizations of space, these are thus best understood as historically and contingently manifested trajectories of much broader phase space potential. Here, the *particularities* of site anchor the *potentialities* of relational forces (Jones, 2009: 494). Relational studies, however, tends to privilege global flows - moving us away from an understanding of how these come to be embedded within the constraints of territory. And yet, Jones argues, ‘regions are being constructed, anchored and mobilized in and through territorially defined political, socio-economic and cultural strategies.’ Phase space, by contrast, ‘acknowledges the relational making of space but insists on the confined, connected, inertial and always context-specific nature of existence and emergence […] on the compatibilities of flow like (networks etc) and more fixed (scales, territories, regions, etc) takes on space’ (Jones, 2009: 489). Rather then merely being the resultant manifestation of global forces, the specificities of ‘discrete territories in the spheres of economics, politics and culture, *matter*.’ (Jones, 2009: 501, emphasis in original). This sentiment is echoed by Evolutionary Economists Martin and Sunley, who remark that,

> ‘The role that spatiality plays in underpinning complex adaptive behaviour is poorly understood. While many of the leading accounts of complexity and complexity economics discuss system movements in ‘state-spaces’ and their adaptive walks on ‘fitness landscapes’, they say little about geographic space and its relation to the adaptive behaviour of individuals and businesses’. (Martin and Sunley 2007: 584–585)

II. Proposition

While both EEG economists and Jones strive to conceptualize how territorial features (political, economic, technological and social) constrain and enable practices associated with the local, little attention has been paid to how *physical* and *material* qualities of localized built environments may play a role in activating potentials for relational unfolding: this despite the fact that each environment holds distinct physical characteristics. Specifically, there is little consideration of how *urban fabric* – the physical manifestation of built form that demarcates spatial extensions within a given localized territory - might impact upon the 'degrees of freedom' available within phase space. What interests me here is the idea that the material artifacts that constitute the urban fabric at specific localities, rather than playing a neutral role, may also 'restrict, constrain, contain and connect the mobility of relational things' (Jones, 2009: 496).

This paper thus focuses upon how traits and particularities of urban fabric (in conjunction with other flows and capacities) modify the phase space potential of a given locale. In what follows, Section One considers how relational analysis tends to gloss over factors related to territorial specificity. I then introduce the idea that specific material artifacts constituting the built environment can support agency by affording certain actions or potentials. Section Two begins to unpack principles derived from EEG studies and Complex Adaptive Systems (CAS) theory, fused and informed by Jones' notion of phase space. I establish a general background as to the range of approaches encompassed under EEG's conceptual umbrella, specifically considering how methodologies drawn from Complexity Science serve to complement and broaden our understanding of Phase Space. Section Three moves on to illustrate examples of urban features that create more affordances in exploring potential trajectories of phase space. I conclude with remarks on implications for policy and theory.

B. Section One: Territorial Anchoring of Relational Space

> "Fluid sociospatial relations and flows require a degree of permanence, of fixity of form and identity – whether in terms of the boundaries of the firm, of national states or of local place […] spaces, flows and circuits are socially constructed, temporarily stabilized in time/space by the social glue of norms and rules, and both enable and constrain different forms of behavior. (Hudson, 2004: 463)

Relational perspectives in geography offer rich insights into ways in which space is constituted by forces and flows, not otherwise captured through analysis at the territorial level. The problematizing of the territory as a fixed and bounded construct (dissected without reference to distanciated forces), has offered a much needed theoretical counterpart to an otherwise narrowly framed understanding of space and place. But despite the conceptual richness relational approaches provide, their *explanatory* power remains vague. Yeung (2005), observes that relational approaches tend to rely upon 'generic concepts of relations and networks [that] are in themselves descriptive categories and therefore devoid of explanatory capacity' (p.42). He argues for the need to move beyond 'recognizing the *de facto* differences in relational geographies to theorizing *explanations of difference'* (2005: 42 emphasis in original). David Harvey concurs, stating that, '[the] reduction of everything to fluxes and flows and the consequent emphasis upon the transitoriness of all forms and positions has it limits and says nothing about nothing' (Harvey (1996), cited in Jones (2009: 495)). Thus, while the positivist stance in geography has been critiqued as making dubious epistemological claims to explaining everything, equally problematic are the ambiguities of a relational stance that would seem to render any sort of explanation impossible (Sayer, 2000).

At first glance, delving into material properties of urban fabric - be it street networks, lot dimensions, landmark locations, building heights and sizes, etc., - might seem far from the project of conceptualizing a relational geography. But this is, in part, due to how design and planning tend to frame these categories of urban form as forming passive *objects* within an urban territory. However, we can reframe these material elements of the urban fabric as possessing *performative* characteristics: that is, being the *carriers* and *constrainers* of agent actions that either afford or inhibit relational potential. They would thus constitute a material parameter of phase space that is typically considered in political, economic or social terms.

In line with this thinking, site ontology, for example, (Schatzki, 2005; Woodward et al., 2010) recognizes specific sites as affording particular kinds of behavior, while always understanding these affordances in relation to human actors – as the "nexus of human practices and material arrangements" (Schatzki, 2005: 465). Schatzki considers "the layout of material settings" (2003: 197) as complementing our understanding of macro and institutional factors by examining how actions are shaped by specific locales, guiding how various socio/economic relations are performed in situ. Thus, features such as 'the organization of offices, passageways, and other rooms' (2003: 197), play a role in constraining behaviors, since action, 'transpires through material arrangements such as these'. Here, the material urban environment is considered an actant that, in tandem with the agency of localized actors, creates specific forms of potentiality within space - supporting a multiplicity of trajectories unfolding within an environment's particular phase space.

Given the past excessive claims of environmental determinism, It is perhaps not surprising that geographers adopt a "healthy skepticism" (Dittmer, 2014) in discussing physicality as affecting spatial trajectories. But environmental *affordances* differ from environmental *determinisms* in that, 'the affordances of an artifact are not things which impose themselves upon humans' actions with, around, or via that artifact. But they do set limits on what it is possible to do with, around, or via the artifact.' (Hutchby, 2001: 453). I therefore wish to 'pay more attention to the material substratum which underpins the very possibility of different courses of action in relation to an artifact' (Hutchby, 2001: 450). Here, the physical environment is neither a passive setting for human actions, nor a determinant cause of human behavior, but rather ' a manifold of action possibilities' (Withagen, De Poel, Araújo, et al., 2012: 251). There is thus a 'mangling' (Pickering, 1993) and an 'imbrication' (Leonardi, 2011) between the human and the (urban) material artifact that enables or constrains possibilities for action and 'entangles the emergence of material agency with human agency' (Pickering, 1993: 577). While the history of particular material settings derives from broader socio-politico and economic forces, once in place they become the setting for future practices, 'taking on a life of their own' long after initial instigating forces have waned. They then vary according to what they do, (or do not) afford to the human agents that occupy them (Withagen, De Poel, Araújo, et al., 2012).

Jason Dittmer outlines how CAS theory allows us to discuss the enabling role of material artifacts without devolving into a return to determinist ontologies. He argues that CAS provides an open-ended, non-deterministic framework that distinguishes between *properties* (features of the artifact) *capacities* (properties that are activated through relations) and *tendencies* (propensities for certain relations to be activated more-so than others). Considering this trio, he indicates that 'tendencies are discovered via mapping the structure of a multidimensional 'possibility space'' (Dittmer, 2014: 392). These 'tendencies and capacities' are what I refer to as affordances, activated within Dittmer's 'possibility space' (again, echoing Jones' 'phase space'). Tendencies are always situated within a broader framework of forces, but nonetheless affect the response to these forces through "the situated articulation of grounded specificities" (Woodward et al., 2010: 276).

I wish to now consider how both EEG and CAS approaches provide us with specific tools that advance our understanding of these grounded specificities and their affect on phase space. I will detour into a general overview of these approaches before returning to a more focused discussion of urban form (the reader interested in a more detailed introduction to CAS may refer to: Bonabeau, et al, 1995; De Wolf & Holvoet, 2004; Gershenson & Heylighen, 2003; F Heylighen, 1997; Kauffman, 1993).

C. Section Two: Principles derived from EEG and CAS theories

Classical Economic and Geographic models conceptualize spaces and economies in ways that 'favor simplification and parameterization of flows and stocks, a process that assumes that the system exists in equilibrium and therefore negates the need to examine changing relationships between system elements.' (Manson, 2001: 406). Like relational geographers, proponents of EEG argue that this conception overlooks the significance of real world, complex, historically contingent and non-linear processes (Foster, 2005). In order to ground this non-linear perspective, EEG has turned to both Evolutionary theories (particularly General Darwinian concepts of variety, selection, and retention of novel characteristics (VSR)) and CAS theory (with its emphasis on the connective nature of economic entities), to understand how distributed firms self-organize and display *emergent* characteristics (Boschma & Frenken, 2006)). While EEG varies in the emphasis it places upon either evolutionary or complexity approaches, there are no inherent contradictions between the two. Rather, "it is the combination of these two perspectives that is most promising." (Boschma and Martin 2010: 6).

In this hybrid conception, situated economies are comprised of agents/firms that both constitute and are constituted by weaves of relations - in the form of energy, matter or information – that flow between them (Holland, 1996). Firms *evolve* their behaviors to increase access to resources and *adapt* their strategies as the *complex* relations of agents that constitute the system itself alters. CAS unpacks the relational attributes between firms that spur economic agglomerations to arise, where the existence of spatial clusters is seen as an emergent property that is neither coordinated by individual firms, nor inherently predictable by virtue of their intrinsic properties (see Holland, 1996; Heylighen, 1999). CAS 'requires Darwinism to complete its explanations' (Hodgson & Knudsen, 2006: 3) and therefore an understanding of the evolutionary trajectories and *capacities* of the firms composing the emerging system is critical.

The term evolution is perhaps misleading, in that it implies ‘survival of the fittest’. However, in CAS and EEG there is no implication that one trajectory is *necessarily* more ‘fit’ than another. Rather, contingent events coupled with reinforcing feedback loops determine trajectories through phase space, leaning towards certain attractor states versus others, in a sequence that is both historical and path dependent. In CAS, the sum total of all possible trajectories composes the phase space. This space is referred to variously as, the ‘design space’, ‘the total set of renderable designs’, and the ‘problem space’ (Beinhocker, 2011). By overlaying a fitness function – that is indicating that some trajectories are more viable than others - onto phase space, a ‘weighted’ topography arises, one that ‘transforms the state space into a *fitness landscape*’ (Heylighen, 1999b: 21). Here, peaks and valleys correspond with different degrees of fitness. Agents chart various courses of action within this landscape, in an effort to ‘increase fitness’: with fitness measured relative to an agent’s ability to grow or succeed (Heylighen, 1999b: 15 Kauffman & Johnsen,1991). Once established, a fit configuration is displaced only in the face of system perturbations (as occurred to the car manufacturing industry in Detroit which collapsed due to large structural disturbances).

EEG considers the firm and its institutional practices as the ‘agent’ - the basic unit of analysis – exploring this fitness landscape. Each firm or agent, ‘interacts with a subset of other agents, and each agent carries only a subset of all economic rules’ (Dopfer, Foster & Potts, 2004: 269). The more agents in the system, the more search strategies or subsets of ‘rules’ deployed. Further, the topography of the landscape constantly shifts as a result of both extrinsic forces and by those unleashed by the actions of the agents themselves – through intrinsic feedback loops that give weight to particular trajectories. The emergence of distinct agglomerations therefore does not imply their permanence, but rather, an evolving performativity that alters in accordance with shifting relational dynamics of the underlying phase space. Further, viable strategies can be pursued in multiple viable trajectories (different peaks stochastically ‘chosen’ at bifurcation points). It is these bifurcations (or splitting of potential pathways) that sidestep environmental determinism: just because certain affordances are in place, does not determine which viable pathway will ultimately be pursued.

Navigating this landscape involves a parallel and iterative evolutionary search process through which each agent, ‘originates, adopts, adapts and retains a novel generic rule’ (Dopfer, Foster & Potts, 2004: 269). Here, ‘the mechanism by which biological systems tune is the result of standard statistical mechanics, whereby ensembles move randomly through all phase spaces of the system over time. […with…] economic returns as the measure of its fitness.’ (Fellman, Post, Wright, et al., 2011: 114) The concept of firms ‘evolving’ within this space is thus not taken to be a loose metaphor of biological processes. Rather, evolution is engaged as a ‘meta-theoretical framework’ (Hodgson, 2009: 170), that explains actual dynamics – ones that apply to a broad class of systems employing search algorithms, of which biological, economic and spatial systems are each part. Thus, firms employ,

> A form of search algorithm that recursively explores a combinatorial problem space, seeking out solutions that are more fit than others according to some notion of fitness […]. Evolution is not the only form of search algorithm (e.g., matching routines for searching databases), nor is it the only algorithm that iteratively searches combinatorial problem spaces across a fitness surface […]. Rather we can identify it as a particular form of search algorithm that uses the Darwinian operators of variation,

> selection and retention to search a design or problem space. (2011: 400)

While EEG's focus is upon the *firm* and its routines as the fundamental unit of analysis (Boschma & Frenken, 2006), I wish to now consider the nature of the *material environment* that the firm occupies. If we can determine how physical components of the urban fabric might constitute the functional analogue of the evolving agent in CAS (in an operational rather than metaphorical manner), then we may begin to tease out how material properties can possess performative characteristics that hold a broader evolutionary range: expanding the potential trajectories of phase space.

D. Section Three - Urban Features that support the exploration of spatial trajectories

> Space makes a difference in terms of settings or contexts […] social processes do not occur tabula rasa but always 'take place' within an inherited space constituted by different processes and objects, each of which have their own *spatial extension, physical exclusivity and configuration*.' (Sayer, 2000: 115, emphasis added)

I. Spatial Cells as Agents

The term 'space' is from the outset problematic, as its use by geographers connote both conceptual and concrete forms. My interest is in the material and concrete aspect of space – explored within urban design - where 'space' is used to denote a particular 'chunk' of material space, defined by the envelope of built form that encapsulates it, and co-existing alongside other envelopes. In most (though not all circumstances) these chunks of urban form are built during similar time periods, with similar economic constraints, taking on similar morphological and typological regularities be they, for example, detached dwellings, tower-blocks, squatter homes or big-box stores. A relational perspective argues that the regularities of these environments are imposed according to the constraints of relational forces.

At the aggregate level these built elements can form a ubiquitous and specific backdrop for a particular locale. This is what is generally referred to as 'urban fabric', or *tissu urbain* (Kropf, 2011). It differs from place to place and is not always homogeneous, being interrupted by particularities such as landmarks. However, in many cases certain ubiquitous features of a given material environment can be identified. These features are delineated by urban designers in terms that describe scale (connoting in this case, size or 'material extension' not relative hierarchy), density (how closely packed the elements are relative to each other with 'closeness' being relatively scaled in accordance with the elements themselves) and material traits (the external features of the built envelop that encapsulates a given spatial unit).

Urban fabric can be analyzed at the aggregate level or at that of the elemental building blocks. In many cases these building blocks exists as functionally contained units – for example a single-family dwelling. That said, urban functions and urban forms do not neatly align into clear morphological categories. Thus, the function of dwelling can occur equally within a detached home or a tower block; that of shopping can occur in either a local corner store or a suburban big box. Hence, in considering a fundamental analytical 'unit' of the material environment, this must vary in accordance with how discreet functions are spatially delineated. An individual apartment on an individual floor of an individual apartment tower, within a built fabric of apartment buildings would constitute the smallest decomposable functional unit of that locale.

This unit does not decompose further (bathrooms, kitchens and bedrooms) as subsequent divisions need to be intrinsically linked in order for the whole to operate. In this particular example, I would consider the spatio-functional unit 'single apartment' to be analogous to EEG's functional unit 'the firm' which is again analogous to CAS's fundamental unit of analysis 'the agent'. Recognizing that the specific characteristics of this material composition of space will vary from setting to setting, it is this *non-decomposable demarcation of functional space* or 'spatial cell' that I wish to consider as analogous to the agent level of CAS.

In CAS theory, agents need to possess certain attributes to operate effectively (maximizing the exploration of phase space and arriving at 'fitter' regimes). First, agents must exist in multiple/parallel iterations at the smallest possible viable size; second, they must have means by which to signal effective behaviors (either directly or through an intermediary substance); and third, they must have the ability to both form larger aggregate bodies and decompose into constituent elements. I shall consider each attribute in turn.

II Minimum Functional Size, Parallel Iterations, Multiple Functional States

In a casual discussion held a few years ago with a business entrepreneur, he described his search for rental space in a downtown center: 'I wanted to open a café bar housed in only 300 square feet, but the smallest space I could rent was over 2000. I knew I could make the project viable, but not at that scale'[i]. After an extensive search, the entrepreneur found suitable space, and opened an enterprise that was immediately successful. He quickly opened a second cafe – in a process made possible because the scope of the first enterprise was small enough for him to test the niche market while minimizing risk. Subsequently, similar cafes sprung up in the city imitating the look and success of his first enterprise: taking advantage of this latent phase space trajectory that could only be manifested within the smallest functional unit described.

John Holland describes how CAS are composed of agents that serve as the system's 'building blocks'. These agents are of minimal possible functional size (that cannot be further decomposed), operate in parallel to one other, and shift behaviors fluidly with minimum friction. This echoes descriptions of firms in EEG, where individual firms constitute the minimal organizational size, many firms operate in parallel, and firms are more effective if they accommodate 'the elastic stretch of institutions and institutional arrangements' (Strambach, 2010: 407). This elasticity is significant as it leverages a broader exploration of phase space, hastening the discovery of fit configurations: particularly if many firms are seeking fitness in parallel. Parallel search hastens the pace of evolution, since 'the more widely a system is made to move through its state space, the more quickly it will end up in an attractor. If it would just stay in place, no attractor would be reached and no self organization could take place.' (Heylighen 1999b: 3)

'Staying in place' or lock-in (Boschma & Lambooy, 1999) represses the ability of CAS agents to fully explore phase space and discover fitter configurations. EEG describes lock-in occurring when established firms become too entrenched – resisting transformation despite economic changes. Here, 'inherited routines and practices, and the sets of social relations that underpin them, can become disadvantageous as economic circumstances change" (MacKinnon et al., 2009: 133). In these cases, any observed persistence of a given system stops being the result of fitness, but is instead a 'perverse resilience, preserving a maladaptive system' (Holling, 2001 p. 11)

When applied to urban form, there are many instances where the persistent nature of the urban fabric is maladaptive, but persists due to the required scope of upheaval, the inflexibility of scale (as in the example at the start of this section) or the overly specialized character of the underlying urban form. Thus, the fact that certain urban forms persist does not necessarily mean that they are particularly fit: they may just be particularly resistant to change. Of course 'unfit' fabric could simply be razed and built anew. But this is not always possible (economically), nor desirable (socially and sustainably). By contrast, when the urban fabric is composed of multiple iterations of easily mutable building stock, there is much greater flexibility afforded to test programmatic variance. Mutability implies not only that the function of the spatial unit can change, but that there is an inherent degree of flexibility such that the built fabric can function both at small individual scales (for small enterprises), as well as aggregating to accommodate larger institutional scales (decomposing again as required). This flexibility increases the likelihood that effective trajectories of phase space will continuously be discovered as economic and cultural conditions shift.

Two cases provide illustrative examples. In Amsterdam the canal architecture forms a ubiquitous built fabric, four to six stories in height, lining the waterfronts. The width of this fabric is the narrowest practical, as buildings were historically taxed based on frontage. Here the smallest decomposable spatial unit (agent) is not the individual canal house but the individual floor plate. This is because each plate can operate independently as an elemental spatial unit that affords sufficient square footage and light to house standard functional urban programmes – be they residential, office or retail. Similarly, in various traditional covered markets, such as the Grand Bazaar in Istanbul, the fabric consists of large numbers of similarly configured spatial units. Each shop is virtually identical in size (the smallest practical unit of space) but each accommodates the testing of different local niche products (carpets, leather-ware, antiquities, etc.).

In the above examples the basic spatial unit (in an imbricated relationship with its owner/renter/shopkeeper) moves along trajectories of programmatic 'mutations' seeking fit configurations. In both cases the fabrics are inherently elastic and the underlying spatial units can flexibly morph (following general Darwinian processes) to house any and all applicable functions. Mutations in either product lines or programmatic configurations can be fluidly explored with minimum internal resistance imposed by the fabric itself. This, combined with the high number of parallel units (iterations), dramatically increases the number of programmatic tests that can be deployed in these environments – Increasing the likelihood of evolving successful mutations. In both examples, there are many potential trajectories of success, each representing different viable configurations of the underlying phase space (whose underlying configuration is distorted according to both relational factors and the actions of the agents themselves).

Thus when we consider the actualized spatial distribution of programs in either the Bazaar, or the Canal District, these are best understood as viable, but historically contingent, configurations drawn from a multitude of phase space potentialities.[ii] Certain material configurations will be successful while others will not. The matter of *why* a mutation is successful pertains to broader relational forces that morph the fitness landscape to generate peaks and valleys (such as when warehouse functions in Amsterdam are replaced by tourist hotels due to a reconfiguration of relational flows). But I am not attempting to unravel the complexity of these relational forces and how they interweave, nor even the impact of individual human actors and their decision-making regarding which mutations to pursue (and how this agency can be restricted due to cultural and political forces). These topics are already the subject of exploration by others. What I do wish to consider is the matter of how successful mutations come to be discovered and if this *in part* pertains to the ease with which the material strata of the immediate locale is primed to respond and adapt to both relational shifts and the volition of the humans that occupy these milieus. It is interesting that the volition of the entrepreneur that I began this section with was initially thwarted by the lack of an appropriate material strata to support his independent vision – even though this vision was both viable and replicable.

CAS permits us to situate the above examples by reference to Stuart Kaufmann's (1993) NK model. In this model *'n'* refers to the number of agents within a given system (in the case of the Grand Bazaar the total number of shops, and in Amsterdam the total number of individual floor plates that can be functionally isolated) and *'a'* refers to the possible 'states' of each agent (in the Bazaar this would be the possible merchandise a shop would specialize in, while in Amsterdam the possible states could be more broadly defined as retail, office, or residential). *'S'* represents the size of the 'possibility space' (or phase space) in each context (Frenken, Marengo & Valente, 1999). Thus, one potential condition of the Bazaar's phase space would be the instance where each and every stall sold leather goods. A second potential phase space would be the condition where every stall sold leather goods, but one single stall sold carpets. The total number of possibility spaces is thus expressed by:

$$S = A_1 \times A_2 \ldots A_N$$

CAS principles describe how the potential phase space for a given locale is expanded when its basic spatial unit is able to occupy multiple states (meaning their material features that are easily reconfigured for other functions) Further, the discovery of fit routines occurs much faster rates when there are a multitude of independent and nimble agents working in parallel, rather then fewer larger agents working sequentially, iteration by iteration. Hence the higher the number of agents (greater values for *n)*[iii] in a given environment, the faster a new peak will be discovered due to the efficiencies achieved by massive parallelism.

Again, the equation above is not intended to suggest that physical features are the *only* factor that impact upon the possibilities of phase space;. I fully recognize that the material is but one factor amongst many and that in many contexts its import may be minimal: but this should not negate that it can still be a factor – and at times a dominant one.

III. Signals, Stigmergy, and Information

The concept of stigmegy (Heylighen, 2006a), as developed within CAS provides another useful tool for understanding how the materiality of space can leverage complex adaptation. The term 'stigmergy' derives from the Greek *stigm-oi* (pricking) and *erg-on* (work). It refers to the idea that actions (work) leave a 'prick' (mark) upon the environment. A classic example from CAS is how the shape of mud deposited in a termite mound prompts the actions of termites subsequently encountering the mound. These prompts yield the construction of a complex architecture despite the fact that the termites do not communicate directly but only *via the intermediary medium* of the mound. All complex systems possess specific material/physical features that act as mediums 'for carrying interactions, communications, or exchanges between the agents that it connects' (Heylighen check page). Thus, a medium for carrying information between charged particles is the electromagnetic field generated between them (Heylighen, 2006a: 12), whereas the medium for carrying information between ants are the pheromone traces left on the ground.

Stigmergy considers how intermediary substances can act as repositories for traces that prompt subsequent agent behaviors. These prompts are reinforced or given 'weight' within an agent's perceptual environment when their density and preponderance increases. Agents operating within such 'weighted' environment have their strategies steered and guided based upon the actions of other agents, rather than randomly exploring all potential trajectories of phase space. The phase space is then constrained and restricted to within certain 'degrees of freedom'. Successful routines are broadcast through stigmergic signals to nearby agents, with these adjusting their strategies for deploying energy and processing resources in response to shifting environmental cues (Holling, 2001).

EEG research parallels this interest in stigmergy through analyzing how information signals benefit co-located firms. Here, co-located firms 'are well informed about the characteristics of their competitors' products and about the quality and cost of the production factors that they use. Advantages of proximity arise from continuous monitoring and comparing' (Bathelt, Malmberg & Maskell, 2004). EEG thus considers signaling, but focuses upon its communicative dimension; with casual social encounters, interpersonal contacts, or labour exchanges between firms forming the basis of information transfer. I wish to consider how evidence of routines and strategies might become *physically* embedded in particular forms of the material environment.

Consider the example of grass. The material properties of grass allow it to be deformed through the imprint of walking: a path is laid. While the grass does not have agency per se, it does have the capacity to hold evidence of moves made by the agents encountering it. Subsequent agents see this trace recorded within the material environment, and adjust their trajectories accordingly. The same is not true of concrete. When encountering a concrete plaza, no previous trajectories of movement are signaled: each path must be traced anew. The two material environments provide very different signals about useful behaviors or shortcuts.

To illustrate further, consider the example of a restaurant district in a mid-sized Canadian city. The area, known as 'Little Italy' spans approximately four city blocks and is comprised of dozens of small Italian restaurants, almost all of which have the *provision for outdoor patio tables*. In the early 2000's one restaurateur, defying norms, opted to open an establishment that featured sushi rather than pizza. Neighboring merchants observed that the sushi restaurant's tables were consistently full (its patio actually expanded) whilst theirs remained partially empty. One by one neighboring establishments converted their enterprises to feature sushi. Over the course of one decade, the district shifted function such that close to 50% of the restaurants now deal exclusively in sushi.[iv] Clearly, the physical provision of outdoor patios did not 'cause' the shift towards sushi. But the fact that the urban environment contained outdoor patios allowed the success of sushi enterprises to be 'marked' and conveyed likely contributed to the speed of neighborhood transition. Had there been no legible evidence of sushi's emerging 'fit' within the local context, there would have been no strategic cues for neighboring enterprises to respond and adapt to.

Similarly, material environments of street facades carry information differently. In visually rich environments such as Bazaars, store-fronts can be shaped by their occupants so as to reveal how space is occupied (in terms of the sale of specific wares) Spatial units are easily mutable, shifting in accordance with new explorations, such that functions both appear and disappear. Street-fronts display which occupancies are thriving (evidenced by turnover of goods), and which are dormant (in the worst case, vacated store-fronts). Merchants in such environments are able to adjust the trajectories of their own programmatic decisions in ways that mimic success *even in the absence of direct communicative exchange*. Similarly, in Amsterdam narrow street facades with large windows make the variety of occupancies clearly visible on the street. Individual merchants and owners are necessarily imbricated in 'displaying' and 'reading' these signals, but the material properties of these urban fabrics (individually controlled street frontages) allow them to be the mediums that carry stigmergic signals, cueing subsequent explorations of phase space.

Further, density of information matters. If an ant colony is composed of only ten ants there are fewer explorations of food sources, such that the stigmergic signals of pheromones evidence only a limited exploration of phase space. Similarly if a street block holds only one large vacant former department store, it becomes unclear if this failure is due to an inherent lack of fit between programme and context, poor management, systemic economic problems, or lack of consumer demand: information resolution is weak. The greater the redundancy of stigmergic signals in an environment, the clearer the information resolution. This redundancy is both a spatial and a temporal characteristic of density. We might have 100 hundred ants distributed in 100 square meters each leaving signals – but the signals they leave do not have enough temporal and spatial density to create a signal for a new entrant. But if placed within a one meter square area these signals begin to cluster, gaining pattern and fidelity. The same can be argued for urban environments. When the material extension of the built environmental fabric is stretched in space signals become diffuse. If we wish to increase fidelity then we must either compress space (by bringing physical elements closer together) or time (by reducing the interval between spatial encounters). Urban scale, being relative, can absorb both – in car environments diffuse big box stores are spatially compressed due to the speed that we encounter them. But in denser urban environments, where the mode of travel is pedestrian, large buildings extended in space limit our ability to encounter information at useful densities.

In the Grand Bazaar, single-storied shops are distributed at approximately every ten feet, meaning that a two-sided one hundred foot street block yields information regarding twenty different 'probes' of that local niche. In Amsterdam the grain is wider, averaging twenty feet per building, but is multi-storied, with functions situated above grade remaining legible. This results in an overall equivalent density of information as the Grand Bazaar case. Both examples offer high densities and thereby higher fidelity of information transfer, as statistical fluctuations and random anomalies - such as a locally ill-suited endeavor being externally subsidized - are cancelled out. Accordingly, while innovation *per se* is enabled by an urban fabric composed of functionally discreet and malleable spatial units, the *nature* of effective functional trajectories can be hastened if the environment stores and broadcasts successful tests at sufficient densities. Conversely, information resolution is hindered in cities of blank-faced multi-storied buildings, particularly when there are restrictions on how surfaces might be altered to carry signals.

CAS again provides tools to understand these dynamics. The level of uncertainty or lack of information about a system can be expressed as '*H', a* term 'introduced by Shannon as a measure of the capacity for information transmission' (Heylighen & Joslyn, 2001:7). H reaches its maximum value when there is no information about the system, or when all physical states for the system are equally probable (maximum entropy). The reduction of H, or the presence of information, serves to reduce the uncertainty of a system.

> H can in general be interpreted as a measure of our ignorance about the system's state [...] Reducing H can be interpreted similarly as either gaining information, or putting a constraint on the system, so as to restrict its freedom of choosing a state. Self-organization as the appearance of coherence or correlation between the system's components is equivalent to the reduction of H. (Heylighen, 1999b: 18)

In the passage above, Heylighen's 'appearance of coherence' can be equated with EEG's emergence of spatial clusters and districts. The reduction of H - brought about by processes that are contingent and path dependent – provides information content that is then reinforced through feedback loops, creating differentiation in what originally may have been relatively neutral space. The actors within the system are then constrained, or 'enslaved' (Haken & Portugali, 2003: 389) as the environment becomes configured such that only certain actions become probable. In the presence of stigmergy or constraining information, districts shift in function and distribution in ways that remain in dynamic equilibrium with the communities they serve.

III. Aggregations and Emergence

Silicon Valley is often cited as the iconic example of a region that emerged to anchor and reinforce a particular kind of innovation (for other examples see Amin and Thrift (2009)). The region leveraged latent intellectual capacity, and amplified these capacities such that other regions offering similar advantages were subsumed. A certain concentration of firms (like a certain concentration of pheromones) created an attractor for subsequent activity. As more agents were attracted to the region, they developed increasingly synergetic capacities. The shape of the 'tech' fitness landscape was modified, creating an attractor within phase space that emerged over time. EEG outlines this process, whereby,

> 'After a period of time [feedback processes encourage] a region to take the lead purely by accident. What is important here is that this lead brings additional advantages (better infrastructure, more specialized services, etc.) to this particular region, due to the agglomeration of firms. In other words, after a threshold (a specific number of firms in the region) has been crossed, the leading region becomes more attractive for new firms to locate there, even if these firms have other locational preferences' (Boschma & Lambooy, 1999: 418).

CAS illuminates these processes further, by describing how emergence entails agents agglomerating into optimized niches (or patches). These patches operate more efficiently to process energy then would agents on their own. Exchanges between patches (where more than one viable activity takes place, meaning there is more then one potential fitness peak), further allow resources to more effectively propagate throughout the system as a whole (Kauffman, 1996). The result is an interweaving of 'local interactions with recirculation, allowing resources to be used over and over again' (Holland, 2012: 159). These synergetic configurations, permit agents to 'differentiate their use of resources over time […with…] minimal overlap in the resources they consume.

In an environment where a certain density of 'successful' tests are exhibited through stigmergic signals, there is an increased likelihood that these strategies will be mimicked, resulting in amplifying feedback loops. Similarly, if a given enterprise is successful, its owner may leverage this success to expand into a neighboring unit of space. In both the case of mimicry or expansion the 'weighting' of information about successful trajectories has increased. This weighting can be thought of as a distortion of phase space – where a fitness peak (or basin of attraction)[v] begins to emerge. Thus, relatively heterogeneous arrays of uses have a propensity to differentially cluster into recognizable sectors, according to path dependent processes. EEG describes how this increases efficiencies due to information transfer between competitors and the sharing of support infrastructure (synergetic functions). Here,

> The initial neutral space is [over time] transformed in real places as the new sectors and new infrastructure networks become spatially concentrated in some regions according to a path dependent process, and trigger the institutional base of these regions to transform and adapt' (Boschma & Frenken, 2006: 290)

To situate these synergetic and emergent clusters within CAS theory, we can return to Kaufmann's NK model, and consider the *'K'* component. 'K' represents the number of connections or relationships that each agent has with others in the system, and also considers the degree to which connectivity affects any agent's overall fitness. In conditions of maximum independence (K= 0), each agent's fitness is unaffected by connections with neighbours. By contrast, in scenarios of maximum complexity (K= N-1), each agent's fitness is reliant upon connections to *all* other agents. Kaufmann argues that in order for resources to propagate optimally, agents must be neither too richly nor too sparsely connected (for a related discussion see Press, 2008).

CAS helps us understand how these synergies are forged due to the increased probability that new entrants will more easily access relevant 'K' linkages to complementary infrastructures, customer bases, and expertise. As positive feedback amplifies certain uses, the number of K connections meaningfully affecting each agent adjusts over time increasing the possibility that emergent clusters of agents - coherent spatial 'niches' of restaurants, houses, offices, souvenir shops, etc. – will manifest. Variations - due in part to their incremental, small-scale and parallel nature - can more easily fine-tune to stabilize at an optimum 'workable' density and extension for a particular niche (neither too thin with lack of K connections nor too crowded with available resources stretched too thin amongst competitors).

Further, Holland (1996) and Simon's (1962) notion of decomposability and 'building blocks' helps to understand why the flexibility and decomposability of the basic spatial units matter. As relational forces shift to place new demands on local environments, those material environments that are composed of independent spatial units that may be incrementally recomposed in new configurations are more adept at forming these synergetic relationships. If we start with an environment composed of minimum functional spatial units, then these may be rendered individually (as, for example dwellings or small businesses) while still holding the capacity to agglomerate and achieve economies of scale for larger institutional functions (offices or hotels). Resources are optimized when CAS agents hold this inherent capacity to either aggregate into mutualist clusters or decompose into self-sufficient units as circumstances change. This notion of fundamental building blocks being important therefore does not imply that one *particular* size or material extension is more functional then another. Rather, it suggests that environments composed of fundamental building blocks afford the greatest possible breadth of material extension (from the small to the large). Once a stable attractor has been discovered, agents are better off aggregating as this creates enough density to support synergetic services. However, if the attractor collapses due to external system perturbations, these same units are able to return to an autonomous state and probe new potential niches (jumping fitness peaks rather than climbing a given peak).

To illustrate, consider how each floor of a canal house serves as a discreet building block: these blocks can serve as independent units of space (restaurant, office, apartments); unify to span levels (single family dwelling) merge with neighboring units to form larger amalgamations (office or hotel block); or differentiate into synergetic components (residences above, grocery below). In each case, the number of K connections between spatial units (whether they operate independently or agglomerate) is fine-tuned for each variation. This flexibility allows a huge array of phase space to be sampled, with random variations resulting in positive synergies. Successful tests are given stigmergic weight, generating positive feedback loops that ultimately lead to the emergence of coherent spatial structure.

While the dynamics that prompt a region to settle into one particular emergent pattern are contingent – and may have emerged in alternate trajectories – once in place they constrain subsequent actions as the limits of the phase space are shifted and fine-tuned. A sole carpet seller on a street of denim dealers may eventually give up and move. Thus, while human agents retain their autonomy, within these emergent patterns their actions come to be increasingly steered by weaves of forces: 'the comings-together of the situation' (Woodward et al., 2012: 216):.

E. Conclusion:

Jane Jacobs (1961) identified the city as a problem of 'organized complexity' unfolding through territorially specific 'on the ground' exchanges. Jacobs extolled the virtues of small-scale urban fabric, believing that this fabric could best mediate day-to-day exchanges and support the lives of local inhabitants. Like Jacobs, I believe it useful to unpack ways in which specific properties of urban fabric differ in affording the relational potentialities of a locale to emerge. CAS provides a lens for us to understand how they differ: why the existence of high densities (*multiple tests*) of malleable spatial units (*agents*) capable of carrying stigmergic signals (*information*) and being both composable and decomposable (*building blocks*) helps enable and accelerate the evolution of functional and synergetic districts (*emergence*). Phase Space provides a complementary theoretical base for acknowledging the contingent and path-dependent nature of these processes, thereby avoiding the problems of environmental determinism. Policymakers and Design practitioners armed with an understanding of these dynamics can move away from seeking optimum solutions for singular equilibrium conditions, towards implementing planning strategies capable of responding to shifting realities: developing environments malleable enough to provide settings for changing relational forces to be grounded.

While I recognize that a multitude of factors beyond the material affect what happens 'on the ground', I remain interested in the milieu where planners and designers have some sphere of influence to, at minimum, enable more rather than less to occur. I would argue that we need to pay more attention to the specific material properties of locales, in order to better 'set the stage' for relational unfolding to occur. As the terms of reference for spatial analysis have expanded dramatically to encompass the cultural, political, infrastructural and economic constraints that shape phase space, the material constraints of localized sites and concretized space have largely been ignored as merely derivative. Any concern with the specificity of local structures at the territorial level and their effect on local actions, has been rendered conceptually moot – even though this is often the only milieu where it remains possible to act. For although structural forces that operate at a distance are seen as constituting and gaining primacy over territorial character, our phenomenological experience of the world *and our ability to affect that world* remain largely embedded in localized settings and practices (Malpas, 2012). If, as Bathelt and Glucker state, "economic action is a process, situated in time and space" (2003: 136) then it is important to know what constrains the time and space that sets the context for action. We need to consider 'specific time/space contexts, discursively and materially formed and concretized' (Hudson, (2004) p. 459), and look 'beyond what is possible […] to focus on what is *compossible* […] in a given socio-spatial field.' (Jones and Jessop, 2010: 1121).

As more and more of the built world expands to dimensions that can only be controlled and occupied by the largest stakeholders (the Walmarts for instance), the latent forces that might be present to support more individuated enterprises are given increasingly fewer options on where to land – with certain viable options no longer being compossible. Whether spatial settings are, at one extreme, the resultant manifestation of broader forces (such as the emergence of big-box environments) or, at the other end of the spectrum, sites of resistance and everyday life (guerilla gardens, pop-up shops, independent start-ups), each material setting, once established, sets into motion subsequent affordances. These affordances are not neutral – they create distortions and new trajectories within phase space. I believe it is worthwhile to have some sort of preliminary (and necessarily incomplete) understanding of what guides these distortions: and whether they amplify or limit future potential.

References:

Amin A (2004) Regions unbound: towards a new politics of place. *Geografiska Annaler: Series B, Human Geography*, 86(1), 33–44.

Amin A (2002) Spatialities of globalisation. *Environment and planning A*, 34(3), 385–400.

Amin A and Thrift N (2009) Neo-Marshallian Nodes in Global Networks*. *International journal of urban and regional research*, 16(4), 571–587.

Bathelt H., Malmberg A and Maskell P (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human geography*, 28(1), 31–56.

Bathelt Harald and Glückler J (2003) Toward a relational economic geography. *Journal of Economic Geography*, 3(2), 117–144.

Beinhocker ED (2011) Evolution as computation: integrating self-organization with generalized Darwinism. *Journal of Institutional Economics*, 7(3), 393–423.

Beinhocker ED (2007) *The origin of wealth: Evolution, complexity and the radical remaking of economics*. Random House.

Bertolini L (2007) 13. Evolutionary urban transportation planning? An exploration. *Applied Evolutionary Economics and Economic Geography*, 279.

Bonabeau E, Dessalles JL and Grumbach A (1995) Characterizing emergent phenomena (1): A critical review. *Revue Internationale de Systemique*, 9(3), 327–346.

Boschma RA and Martin RL (2010) *The handbook of evolutionary economic geography*. Edward Elgar Publishing.

Boschma Ron and Frenken K (2011) The emerging empirics of evolutionary economic geography. *Journal of Economic Geography*, 11(2), 295–307.

Boschma Ron and Frenken K (2006) Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. *Journal of economic geography*, 6(3), 273–302.

Boschma Ron and Lambooy JG (1999) Evolutionary economics and economic geography. *Journal of evolutionary economics*, 9(4), 411–429.

De Wolf T and Holvoet T (2004) Emergence and Self-Organisation: a statement of similarities and differences. *Lecture Notes in Artificial Intelligence*, 3464, 96–110.

DeLanda M (2005) *Intensive Science & Virtual Philosophy*. New edition. Continuum.

Dittmer J (2014) Geopolitical assemblages and complexity. *Progress in Human Geography*, 38(3), 385–401.

Dopfer K, Foster J. and Potts J (2004) Micro-meso-macro. *Journal of Evolutionary Economics*, 14(3), 263–279.

Fellman PV, Post JV, Wright R, et al. (2011) Adaptation and Coevolution on an Emergent Global Competitive Landscape. In: Minai AA, Braha D, and Bar-Yam Y (eds), *Unifying Themes in Complex Systems*, Springer Berlin Heidelberg, pp. 113–120.

Foster John (2005) From simplistic to complex systems in economics. *Cambridge Journal of Economics*, 29(6), 873–892.

Frenken K, Marengo L and Valente M (1999) Interdependencies, Nearly-Decomposability and Adaptation. In: Brenner T (ed.), *Computational Techniques for Modelling Learning in Economics*, Boston, MA, Springer US, pp. 145–165.

Gershenson C and Heylighen Francis (2003) When Can we Call a System Self-organizing? *nlin/0303020*.

Haken H and Portugali J (2003) The face of the city is its information. *Journal of Environmental Psychology*, 23(4), 385–408.

Harrison S, Massey D and Richards K (2006) Complexity and emergence (another conversation). *Area*, 38(4), 465–471.

Harvey D and Braun B (1996) *Justice, nature and the geography of difference*. Wiley Online Library, Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1541-0064.1999.tb01365.x/abstract (accessed 17 January 2013).

Heylighen F (1997) The Growth of Structural and Functional Complexity during Evolution. In: *The Evolution of Complexity*, Kluwer, Dordrecht.

Heylighen F. (2006a) Mediator Evolution: a general scenario for the origin of dynamical hierarchies. *Worldviews, Science and Us.(Singapore: World Scientific)*.

Heylighen F. (1999a) The growth of structural and functional complexity during evolution. *The evolution of complexity*, 17–44.

Heylighen F. (1999b) The Science Of Self-Organization And Adaptivity. *Knowledge Managemen, Organizational Intelligence and Learning, and Complexity, in: The encyclopedia of life support systems EOLSS*, 253–280.

Heylighen F. (2006b) Why is Open Access Development so Successful? Stigmergic organization and the economics of information. *Arxiv preprint cs/0612071*, Available from: http://arxiv.org/abs/cs/0612071 (accessed 28 August 2012).

Heylighen F. and Joslyn C (2001) Cybernetics and second order cybernetics. *Encyclopedia of physical science & technology*, 4, 155–170.

Hodgson GM and Knudsen T (2006) Why we need a generalized Darwinism, and why generalized Darwinism is not enough. *Journal of Economic Behavior & Organization*, 61(1), 1–19.

Holland J (1996) *Hidden Order: How Adaptation Builds Complexity*. Basic Books.

Holland J (2012) *Signals and Boundaries: Building Blocks for Complex Adaptive Systems*. The MIT Press.

Holling CS (2001) Understanding the complexity of economic, ecological, and social systems. *Ecosystems*, 4(5), 390–405.

Hudson R (2004) Conceptualizing economies and their geographies: spaces, flows and circuits. *Progress in Human Geography*, 28(4), 447–471.

Hutchby I (2001) Technologies, texts and affordances. *Sociology*, 35(2), 441–456.

J. G. Lambooy and Boschma R (2001) Evolutionary economics and regional policy. *The Annals of Regional Science*, 35(1), 113–131.

Jacobs J (1961) *The death and life of great American cities*. Vintage.

Jones M. (2009) Phase space: geography, relational thinking, and beyond. *Progress in Human Geography*, 33(4), 487–506.

Jones M and Jessop B (2010) Thinking State/Space Incompossibly. *Antipode*, 42(5), 1119–1149.

Kauffman S (1996) *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*. Oxford University Press, USA.

Kauffman S (1993) *The origins of order: Self-organization and selection in evolution*. Oxford University Press, USA.

Kauffman S and Johnsen S (1991) Coevolution to the edge of chaos: Coupled fitness landscapes, poised states, and coevolutionary avalanches. *Journal of Theoretical Biology*, 149(4), 467–505.

Koroglu BA, Eceal TÖ and Ugular A (2010) The Story of a Jewelry Cluster in Istanbul Metropolitan Area: Grand Bazaar (Kapalıçarsı). *Gazi University Journal of Science*, 22(4), 383–394.

Kropf K (2011) Morphological Investigations : Cutting into the Substance of Urban Form. *Built Environment*, 37(4), 393–408.

Leonardi PM (2011) When flexible routines meet flexible technologies: Affordance, constraint, and the imbrication of human and material agencies. *MIS quarterly*, 35(1), 147–167.

MacKinnon D, Cumbers A and Pike A (2009) Evolution in economic geography: institutions, political economy, and adaptation. *Economic Geography*, 85(2), 129–150.

Malpas J (2012) Putting space in place: philosophical topography and relational geography. *Environment and Planning D: Society and Space*, 30(2), 226–242.

Manson S (2001) Simplifying complexity: a review of complexity theory. *Geoforum*, 32(3), 405–414.

Martin R and Sunley P (2007) Complexity thinking and evolutionary economic geography. *Journal of Economic Geography*, 7(5), 573–601.

Massey D (1999) Space-time, science and the relationship between physical geography and human geography. *Transactions of the Institute of British Geographers*, 24, 261–276.

Melton MA (1958) Correlation structure of morphometric properties of drainage systems and their controlling agents. *The Journal of Geology*, 442–460.

O'Sullivan D [1] (2004) Complexity science and human geography. *Transactions of the Institute of British Geographers*, 29, 282–295.

Pickering A (1993) The mangle of practice: Agency and emergence in the sociology of science. *American Journal of Sociology*, 559–589.

Press K (2008) Divide to conquer? Limits to the adaptability of disintegrated, flexible specialization clusters. *Journal of Economic Geography*, 8(4), 565–580.

Prigogine I and Stengers I (1984) *Order Out of Chaos*. Shambhala.

Richards K (2004) Space, time and science" individuals, emergence and geographies of space and place. In: *Unifying geography: common heritage, shared future*, London, Routledge, pp. 327–52.

Sayer A (2000) *Realism and social science*. Sage Publications Limited.

Schatzki T (2003) A New Societist Social Ontology. *Philosophy of the Social Sciences*, 33(2), 174–202.

Schatzki T (2005) Peripheral Vision: The Sites of Organizations. *Organization Studies*, 26(3), 465–484.

Simon HA (1962) The architecture of complexity. *Proceedings of the American Philosophical Society*, 106, 467–482.

Strambach S (2010) 19 Path dependence and path plasticity: the co-evolution of institutions and innovation–the German customized business software industry. *The Handbook of Evolutionary Economic Geography*, 406.

Urry J (2003) *Global complexity*. Wiley-Blackwell.

Urry J (2005) The Complexities of the Global. *Theory Culture Society*, 22(5), 235–254.

Withagen R, De Poel HJ, Araújo D, et al. (2012) Affordances can invite behavior: Reconsidering the relationship between affordances and agency. *New Ideas in Psychology*, 30(2), 250–258.

Woodward K, III JJ and Marston S (2010) Of eagles and flies: Orientations toward the site. *Area*, 42(3), 271–280.

Woodward K, Jones JP and Marston S a. (2012) The politics of autonomous space. *Progress in Human Geography*, 36(2), 204–224.

Yeung HW (2005) Rethinking relational economic geography. *Transactions of the Institute of British Geographers*, 30(1), 37–51.

[i] Paraphrased from author's and subject's discussion (2010) as recollected by both in 2014

[ii] For more on the Grand Bazaar's evolution, see (author name) in IJIA 2015 (forthcoming)

[iii] In a similar vein, Bertolini's study of Amsterdam's transportation infrastructure, suggests that to enhance 'resilience and adaptability […the] transportation system could be broken down into smaller components and realized in a more incremental way' (Bertolini, 2007: 2017)).

[iv] Author's observations

[v] "Basins of Attraction" and "Fitness Peaks" being different metaphors for the same concept.