Complex Adaptive Systems & Urban Morphogenesis

Analyzing and designing urban fabric informed by CAS dynamics

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Preamble

For as long as I can remember, I have been interested in understanding the nature of urban spaces that have a convivial 'alive' quality to them. Ones that are vibrant, that are diverse, and that embody what Christopher Alexander calls 'a *Quality Without a Name'*. Years ago, while working on my Master's Thesis in Architecture, I began to try to understand the nature of how such places came to be. Inspired by readings in Quantum Physics, I began to believe that the nature of reality was based not upon the atomistic perspective that had fuelled the Newtonian worldview, but instead upon a process-driven ontology where the fundamental building blocks of reality – and of life - had to do with interactions rather than objects. I wanted to better understand how this perspective might inform thinking on architecture and urbanism conceived around process rather than form. That said, it was not until I came upon Complex Adaptive Systems (CAS) perspectives that I realized CAS could provide the necessary conceptual tools to gain this understanding: tools framing what a process-driven perspective might entail. CAS research looked at what appeared to be stable forms, but described these forms as emergent assemblages of disparate, intertwining processes. If I could understand the fundamental nature of such processes - the kinds of factors enabling or hindering them, perhaps I could better understand how such processes might steer the built environment.

Shortly after finishing my Master's degree I came upon Steven Johnson's book, 'Emergence'. In it, he observes how streets in medieval cities came to be specialized to deliver a particular product: gold or fabrics, hats or shoes, for example. He argues that this clustering of similar products *emerges* as a result of complex interactions on the ground. Over time, these interactions sedimentize, or as John Urry would describe, become 'moored' (2003) such that a particular street, block, or district focuses upon a specific kind of urban offering, product, or event. Johnson points to how this kind of emergence occurs in many circumstances, from ant colonies to cities, but until recently we have not known how to unpack the dynamics whereby such organization occurs. However, in recent years a growing body of research – through the emerging field of Complex Adaptive Systems theory - has begun to unpack such systems.

My initial enthusiasm for pursuing research in CAS was borne out of the hope that CAS perspectives might provide an alternative way to envision the creation of functional urban orders that arise through emergent, evolutionary processes, rather than top-down master plans. Coming from practice, I had seen top-down planning often fail to adequately navigate uncertainties. All too often, planning schemes either became out-of-date before the ink upon them had dried or (if executed as conceived), failed to materialize on the ground the urban qualities depicted on paper. This background in practice made me wish to understand CAS dynamics as they unfold within the specificity of urban form.

I began this investigation into an alternative means of form-making more than a decade ago, initially through design competitions that served as early testing grounds for conceptualizing designs that conceived of form not as a static 'product', but instead as a means to enable a process. These explorations occurred prior to any knowledge of the broader spectrum of research into CAS and urban processes. Since then, I have gained a deep appreciation of how CAS can be used to understand different forms of complex unfolding - be they economic, social, communicative, etc. That said, the Ph.D. remains attuned to the specifics of urban design practice and is therefore premised upon the notion that the specifics of material urban form can be considered as a necessary component of an urban complex entity: one that provides the physical scaffold with which to support and balance a broad range of forces - economic, social, and political - within its midst. So, the question becomes, what *kinds* of urban morphological conditions can we, as practitioners, design that would have the capacity to evolve – to 'discover' viable configurations to support CAS processes - but this through *emergent* rather than command and control mechanisms. The following manuscript aims to work towards a deeper understanding of how this might occur.

Acknowledgements

I wish to acknowledge the support of my supervisor, Dr. Stephen Read, and the Chair of Spatial Planning and Urbanism, Professor Vincent Nadin, for their encouragement over the years as I have completed this work. Both have been exceedingly patient with me - even as the work has gone on hold at various times due to unforeseen life events. At all times, they have encouraged me and provided me with both practical and emotional support, particularly with regards to providing me with sufficient time to complete the work and enabling me to travel to meet with academic peers in Europe in order to present and refine my thinking.

Many people have helped in the fleshing out of ideas contained in this dissertation. The articles in this Ph.D. all began as conference papers and have greatly benefitted from the vetting that occurred over the course of time, in particular through discussions with members of the AESOP satellite group for Complexity and Self Organization. I wish in particular to thank Ward Rauws for his ongoing efforts to direct this group, and for coordinating such amazing venues for conferences that included both formal and informal gatherings. I also wish to thank the editors of the various journals who corresponded with me about the submitted articles. Never having submitted to academic journals, I was pleasantly reassured by many of them as I went through many versions of editing in response to the thoughtful reviewer comments. It was a privilege to be the beneficiary of the insight of these anonymous reviewers. The articles published as part of this Ph.D. have greatly matured in depth and scope as a result of their suggestions and input.

Deep appreciation also goes to my Chair at Iowa State University, Deborah Hauptmann, in particular for providing me with an opportunity to teach a seminar course on my research topic. It has been a privilege to share this research with students at Iowa State, and through their feedback, develop my own ideas further. I owe a huge debt of gratitude to this talented group of young designers, who have helped push ideas about complexity forward, particularly into domains where digital interfaces begin to engage and mediate urban spaces. A number of the papers in this Dissertation would not have been possible without the discussions and input of these incredibly talented and engaged students. My Graduate Assistant, Sean Wittmeyer, merits special mention for his enthusiasm and for his work developing code for my website.

Finally, I wish to thank my husband, Stan Duncan, for so many things: having the patience to listen to me as I read aloud each and every final version of these papers prior to their submission; bringing me coffee and keeping the home fires burning while I worked; nodding supportively as I hashed out ideas using obscure terminology for which he had no reference point; and always keeping an unwavering faith in my ability to achieve this degree - even when I doubted it myself. I am ever so fortunate to have you in my life.

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Summary

This thesis looks at how cities operate as Complex Adaptive Systems (CAS). It focuses on how certain characteristics of urban form can support an urban environment's capacity to self-organize, enabling emergent features to appear that, while unplanned, remain highly functional. The research is predicated on the notion that CAS processes operate across diverse domains: that they are 'generalized' or 'universal'. The goal of the dissertation is then to determine how such generalized principles might 'play out' within the urban fabric. The main thrust of the work is to unpack how elements of the urban fabric might be considered as elements of a complex system and then identify how one might design these elements in a more deliberate manner, such that they hold a greater embedded capacity to respond to changing urban forces. The research is further predicated on the notion that, while such responses are both imbricated with, and stewarded by human actors, the specificities of the material characteristics themselves matter. Some forms of material environments hold greater intrinsic physical capacities (or affordances) to enact the kinds of dynamic processes observed in complex systems than others (and can, therefore, be designed with these affordances in mind). The primary research question is thus:

What physical and morphological conditions need to be in place within an urban environment in order for Complex Adaptive Systems dynamics arise - such that the physical components (or 'building blocks') of the urban environment have an enhanced capacity to discover functional configurations in space and time as a response to unfolding contextual conditions?

To answer this question, the dissertation unfolds in a series of parts. It begins by attempting to distill the fundamental dynamics of a Complex Adaptive System. It does so by means of an extensive literature review that examines a variety of highly cited 'defining principles' or 'key attributes' of CAS. These are cross-referenced so as to extract common features and distilled down into six major principles that are considered as the generalized features of any complex system, regardless of domain. In addition, this section considers previous urban research that engages complexity principles in order to better position the distinctive perspective of this thesis. This rests primarily on the dissertation's focus on complex urban processes that occur by means of materially enabled in situ processes. Such processes have, it is argued, remained largely under-theorized. The opening section presents introductory examples of what might be meant by a 'materially enabling' environment.

The core section of the research then undertakes a more detailed unpacking of how complex processes can be understood as having a morphological dimension. This section begins by discussing, in broad terms, the potential 'phase space' of a physical environment and how this can be expanded or limited according to a variety of factors. Drawing insights from related inquiries in the field of Evolutionary Economic Geography, the research argues that, while emergent capacity is often explored in social, economic, or political terms, it is under-theorized in terms of the concrete physical sub-strata that can also act to 'carry' or 'moor' CAS dynamics. This theme is advanced in the next article, where a general framework for speaking about CAS within urban environments is introduced. This framework borrows from the terms for 'imageability' that were popularized by Kevin Lynch: paths, edges, districts, landmarks, and nodes. These terms are typically associated with physical or 'object-like features' of the urban environment – that is to say, their image. The terminology is then co-opted such that it makes reference not simply to physical attributes, but rather to the complex processes these attributes enable. To advance this argument, the article contrasts the static and 'imageable' qualities of New Urbanism projects with the 'unfolding' and dynamic qualities of complex systems - critiquing NU proponents as failing to appreciate the underlying forces that generate the environments they wish to

emulate. Following this, the efficacy of the re-purposed 'Lynchian' framework is tested using the case study of Istanbul's Grand Bazaar. Here, specific elements of the Bazaar's urban fabric are positioned as holding material agency that enables particular emergent spatial phenomena to manifest. In addition, comparisons are drawn between physical dynamics unfolding within the Bazaar's morphological setting (leading to emergent merchant districts) and parallel dynamics explored within Evolutionary Economic Geography).

The last section of the research extends this research to consider digitally augmented urban elements that hold an enhanced ability to receive and convey information. A series of speculative thought-experiments highlight how augmented urban entities could employ CAS dynamics to 'solve for' different kinds of urban optimization scenarios, leading these material entities to self-organize (with their users) and discover fit regimes. The final paper flips the perspective, considering how, not only material agency, but also human agency is being augmented by new information processing technologies (smartphones), and how this can lead to new dances of agency that in turn generate novel emergent outcomes.

The dissertation is based on a compilation of articles that have, for the most part, been published in academic journals and all the research has been presented at peer-reviewed academic conferences. An introduction, conclusion, and explanatory transitions between sections are provided in order to clarify the narrative thread between the sections and the articles. Finally, a brief 'coda' on the spatial dynamics afforded by Turkish Tea Gardens is offered.

Samenvatting

In dit proefschrift kijken we hoe steden functioneren als complexe adaptieve systemen (CAS). Het proefschrift richt zich op de vraag hoe bepaalde stedelijke vormkenmerken het zelforganiserend vermogen van een stedelijke omgeving kunnen ondersteunen en hoe ze kunnen bijdragen aan het ontstaan van nieuwe mogelijkheden die weliswaar niet gepland zijn, maar wel zeer functioneel. Het onderzoek berust op de idee dat CAS-processen in diverse domeinen voorkomen: dat ze 'gegeneraliseerd' of 'universeel' zijn. Het doel van het proefschrift is om te kijken hoe dergelijke gegeneraliseerde principes kunnen uitpakken binnen de structuur van de stad. Het belangrijkste streven van het werk is om bloot te leggen hoe elementen van de stadsstructuur kunnen worden beschouwd als elementen van een complex systeem en om vervolgens aan te duiden hoe je deze elementen op een doelbewustere manier zou kunnen ontwerpen, zodat ze een grotere intrinsieke capaciteit hebben om te reageren op veranderende krachten in de stad. Het onderzoek is verder gebaseerd op de idee dat, hoewel het de mensen zelf zijn die reageren, de specifieke materiële kenmerken ook van belang zijn. Sommige vormen van materiële omgevingen dragen grotere intrinsieke fysieke capaciteiten (of affordances) in zich dan andere om het soort dynamische processen uit te voeren dat in complexe systemen wordt waargenomen, en kunnen daarom met het oog op deze affordances worden ontworpen. De primaire onderzoeksvraag is dus:

Welke fysieke en morfologische omstandigheden moeten er in een stedelijke omgeving heersen om de dynamiek van complexe adaptieve systemen te laten ontstaan, zodanig dat de fysieke componenten (of 'bouwstenen') van de stedelijke omgeving een grotere capaciteit hebben om functionele configuraties in ruimte en tijd bloot te leggen als reactie op zich ontwikkelende contextuele omstandigheden?

Het antwoord op deze vraag ontvouwt zich in het proefschrift in diverse stadia. Om te beginnen proberen we de fundamentele dynamiek van een complex adaptief systeem te destilleren. Dit gebeurt aan de hand van een uitgebreid literatuuronderzoek waarin een breed scala aan veel geciteerde 'definiërende principes' of 'sleutelattributen' van CAS wordt onderzocht. Hieruit worden gemeenschappelijke kenmerken geëxtraheerd en gedestilleerd in zes belangrijke principes die worden beschouwd als gegeneraliseerde kenmerken van een willekeurig complex systeem, ongeacht het domein. Daarnaast wordt in deze sectie ingegaan op eerder stedenbouwkundig onderzoek naar complexiteitsprincipes, zodat we het onderscheidend perspectief van deze dissertatie beter kunnen positioneren. Dit berust vooral op de focus van het proefschrift op complexe stedelijke processen die optreden door middel van materieel gefaciliteerde in-situ processen. Dergelijke processen hebben tot nu toe relatief weinig theoretische aandacht gekregen. In de openingssectie presenteren we inleidende voorbeelden van wat zou kunnen worden bedoeld met een 'materieel faciliterende' (materially enabling) omgeving.

In de kernsectie van het onderzoek wordt vervolgens uitvoeriger ontrafeld hoe complexe processen kunnen worden opgevat als processen met een morfologische dimensie. In dit hoofdstuk wordt eerst in grote lijnen ingegaan op de potentiële 'faseruimte' van een fysieke omgeving en hoe deze kan worden uitgebreid of beperkt aan de hand van verschillende factoren. Met behulp van gerelateerde inzichten uit de evolutionaire economische geografie beredeneren we dat nieuwe capaciteiten wel vaak worden onderzocht op hun sociale, economische, of politieke aspecten, maar minder voor wat betreft de concrete fysieke substrata die ook CAS-dynamiek kunnen 'dragen' of 'vastleggen'. Dit thema wordt verder uitgediept in het volgende artikel, waarin een algemeen kader wordt geïntroduceerd voor het bespreken van CAS binnen stedelijke milieus. Dit kader maakt gebruik van de termen voor 'verbeeldbaarheid' (imageability) die populair zijn gemaakt door Kevin Lynch: paden, randen, wijken,

landmarks en knooppunten. Deze termen worden doorgaans in verband gebracht met fysieke of 'objectachtige' kenmerken van de stedelijke omgeving, dat wil zeggen met hun beeld. De terminologie wordt op zodanige wijze overgenomen dat de termen niet alleen verwijzen naar de fysieke kenmerken, maar ook naar de complexe processen die door deze kenmerken worden gefaciliteerd. Om dit argument uit te werken stellen we in het artikel de statische en 'verbeeldbare' kwaliteiten van New Urbanism-projecten tegenover de 'zich ontwikkelende' (unfolding) en dynamische kwaliteiten van complexe systemen. Hierbij is de kritiek op voorstanders van New Urbanism dat ze de onderliggende krachten die de omgevingen genereren die ze willen nabootsen, niet voldoende op waarde schatten. Vervolgens wordt de effectiviteit van dit aangepaste 'Lynchiaanse' kader getest aan de hand van de casus van de Grote Bazaar van Istanboel. Van specifieke elementen van de stadsstructuur van de Bazaar wordt gesteld dat ze beschikken over een materiële werking die het mogelijk maakt dat bepaalde nieuwe ruimtelijke verschijnselen zich manifesteren. Daarnaast worden vergelijkingen gemaakt tussen de fysieke dynamiek die zich ontwikkelt binnen de morfologische context van de Bazaar (en die leidt tot opkomende handelswijken) en parallelle dynamiek die wordt onderzocht binnen de evolutionaire economische geografie.

In de laatste sectie van het onderzoek breiden we dit onderzoek uit naar digitaal verrijkte (augmented) stedelijke elementen die een groter vermogen hebben om informatie te ontvangen en over te brengen. Een reeks speculatieve gedachte-experimenten laat zien hoe verrijkte stedelijke entiteiten de CAS-dynamiek zouden kunnen gebruiken om verschillende soorten stedelijke optimalisatiescenario's af te leiden, waardoor deze materiële entiteiten zichzelf (samen met hun gebruikers) zouden kunnen organiseren en geschikte structuren zouden kunnen ontdekken. In het afsluitende artikel wordt het perspectief omgedraaid en wordt bekeken hoe niet alleen materiële, maar ook menselijke werking (agency) wordt verrijkt met nieuwe informatietechnologieën (smartphones), en hoe dit kan leiden tot een nieuw spel met agency waar weer nieuwe resultaten uit kunnen ontstaan.

Het proefschrift is gebaseerd op een compilatie van artikelen die voor het grootste deel zijn gepubliceerd in wetenschappelijke tijdschriften. Al het onderzoek is gepresenteerd op wetenschappelijke conferenties met peer review. Tussen de secties worden inleiding, conclusie en verklarende overgangen gepresenteerd om de narratieve lijn tussen de secties en de artikelen te verduidelijken. Ten slotte wordt er een kort 'coda' over de ruimtelijke dynamiek van de Turkse theetuinen gepresenteerd.

PART 1 Introduction

The introduction begins by establishing the research context that the thesis relates to. Having set the context, I situate the work within other research, identifying the specific area that I am looking to contribute to. I then outline my key research question and the research tasks required to answer this question. I follow with the methodological steps required to address each research task, discussing how the various chapters of the dissertation each contribute to developing the argument of the overall thesis. I then go on to discuss the research limits. I conclude the introduction with a number of notes on the manuscript organization, providing an overview of the structure of the dissertation (Literature and Precedents, Hypothesis, Case Studies, Future Directions, and Conclusion), as well as some final notes on reading the manuscript.

1 Research Outline

§ 1.1 **Research Background**

Complex Adaptive Systems theory is a field of study developed in the natural sciences, where it refers to a very specific range of systems. These systems involve a large number of agents that together generate unpredictable, organized global behaviours predicated upon agent interactions (Holland, 1995; Kauffman, 1996). CAS, therefore, involve 'bottom-up' rather than 'top-down' dynamics, and the study of CAS involves understanding how local interactions are nonetheless able to generate global order. The principles of CAS theory, (introduced in depth within Chapter Two of the dissertation and re-introduced in many of the subsequent chapters) are briefly outlined here with a few introductory comments to establish a preliminary background for the topic.

CAS is an outgrowth of earlier work in Cybernetics (Ashby, 1947) and Systems Theory (von Bertalanffy, 1968). This foundational work concerned itself with investigating systems themselves - rather than the objects within systems - as a fundamental field of inquiry. The goal of this work was to understand objects not as entities in and of themselves, but instead as component parts of larger systems that the objects contributed to, and stabilized. However, this research remained largely predicated upon perceiving systems as 'closed': that is, as having a singular optimum, with the goal of a system being to move towards an 'equilibrium' state. Complexity Sciences, by contrast, turns to the analysis of non-linear systems – ones in which multiple equilibria exist and where the manifestation of a particular system state is the result of historical unfolding (Manson, 2001). Formulating and disseminating the burgeoning sciences of complexity was spearheaded in the 1980s at the Santa Fe Institute, whose mission was to develop a general theory of complex systems and self-organizing processes applicable to both the natural and social sciences (Heylighen, 1999b; Martin and Sunley, 2007b). From these beginnings, CAS research found traction in a wide array of disciplines and in research conducted around the world.

The core of our general fascination with Complex Adaptive Systems is reflected in the kinds of examples that tend to be employed when describing such systems: the uncanny ability of ants to self-organize, for termites to collectively build complex mounds, or for heated water molecules to churn in regulated patterns (Benard rolls). In each case, it is the unexpectedness of order appearing in the absence of top-down control that elicits our surprise and interest.

The study of Complex Adaptive Systems (CAS) theory is now firmly entrenched as a key area of research implicated within a wide array of disciplines, with urbanism being no exception (Sengupta et al., 2016). There are a growing number of urban theories that incorporate CAS perspectives within their conceptual frameworks, including work in computational modelling (Batty, 2008), communicative planning (Healey, 2007), and the broader relational and assemblage approaches to geography (Anderson and Mcfarlane, 2011; Hillier, 2008; Inness and Booher, 1999). The interest in the contingent dynamics of complex systems corresponds with a growing sense of dis-ease with the notion of predictable futures and increased skepticism towards traditional 'plan-making' (Graham and Healey, 1999).

CAS studies are applicable to the urban domain for a variety of reasons. First, CAS demonstrate an 'alive' quality: a feature that is potentially important in the creation of convivial urban spaces. Second, CAS are able to 'learn' over time: meaning that more robust configurations of the urban fabric may potentially be discovered if urban environments enabled CAS dynamics to unfold. Third, CAS are robust in the face of external shocks – hence urban environments informed by CAS dynamics are likely to be more resilient and resistant to large-scale failure (which too often plague large-scale master-planned schemes). Finally, a CAS perspective places an emphasis on relations rather than objects – in keeping with an increasingly relational turn in contemporary geography - a subject that I return to in Chapter Three (see also Anderson & Mcfarlane, 2011; Graham & Healey, 1999).

That said, CAS theory's appropriation within planning and urbanism (and within the humanities in general) has displayed a tendency to abandon the specificities of the source domain in favour of a much more general, metaphoric appropriation (Chettiparamb, 2006). This is not to say that such usage has not proven useful – the richness of CAS derived metaphors allows us to consider new perspectives, and opens new conversations in a host of fields, including that of urbanism and planning (Thrift, 1999). Many insights have been gained by adopting a non-linear, process driven ontology wherein both time and history matters. But while there have been gains there are also losses. Too often 'Complexity' has made its way into the urban lexicon as a popular buzz word that refers to anything and everything that we have difficulty understanding (Thrift, 1999). In much of the design and planning literature, there is little disambiguation made between notions of what is 'complicated' versus what is 'complex', (Cilliers, 1998). The resulting overuse of complexity terminology has, therefore, at times rendered it meaningless.

Concurrently, while there have been moves towards embracing an increasingly process-driven 'relational' ontology in geography and planning, this has tended to be limited to more theoretically driven discourses regarding the political, economic and cultural drivers that inform 'spatiality' rather than the physical characteristics of space itself (Malpas, 2012). This points to a general disconnect within planning scholarship that has shifted away from 'plan-making' (the substance of design) to 'the making of plans' (the processes that inform plan-decision making (see Milroy, 2010)). With this lack of interest in the 'stuff of space,' there is little in the way of clear methodologies for formulating a physical design perspective that does not involve some sort of projection of future physical states. This absence is discussed in Chapter Three, which notes that *'the planning community has neglected its scholarly interest in developing new insights into the nature of spatial relationships, and in the articulation of space in relational and non-Euclidean ways'* (Davoudi and Pendlebury, 2010, page 638).

Accordingly, despite a growing body of urban discourse engaging complexity (including computational, communicative, and assemblage approaches), these approaches engage more so with the *subject* of planning (planning practices, actors, power-structures, dialogues, stories, etc.), than with the *object* of planning (buildings, plots, streets, and squares). Chapters Two and Four observe that, despite CAS being a major topic of research within urbanism and planning, there is a dearth of literature regarding how CAS dynamics might be operationalized in physical conditions: instances where CAS processes are performed through the medium of urban form in situ – not in virtual forms situated within the confines of computer models, nor in communicative forms involving planning dialogue.

I argue that, while many have extolled the benefits of adopting a CAS perspective to urban design problems, (see for example authors in Portugali, Meyer, Stolk, & Tan, 2012) little explicit attention has been directed towards understanding the role that formal morphological traits may play in enabling emergent unfolding to occur over the course of time. Further, the tendency to abandon examining the

specific dynamics of CAS - sidestepping efforts to understand how order is achieved in such systems, and instead loosely labelling all complicated systems as 'complex' – can easily lead to examining each and every system as being 'complicated' without actually gaining anything from the specificity of how CAS operate. Angelique Chettiparamb, in her paper '*Metaphors in Complexity and Planning*', reacts to this rather loose appropriation of CAS, stating that:

…the re-conceptualization must be taken further to achieve three objectives: to explore the connotative meanings associated with complexity theory as revealed in different source domains from which the theory originates […] to undertake a fuller and more detailed exploration of the abstracted features so as to yield the relational structure within the abstraction in finer detail; and to undertake empirical work to detail out how the imported structural mapping plays out in the new target domain, thereby yielding new insights relevant to this domain, while changing and contextualizing the received concepts. (Chettiparamb, 2006, page 82)

§ 1.2 Situating the Research

To Chettiparamb's point, work at the Santa Fe Institute, while open to cross-disciplinary fertilization, is predicated on the notion that CAS principles - whether applied in biology, neurology, economics, or cities – can be framed through a generalized meta-framework where insights from one area are operationalized when working within another. The Santa Fe Institute aims to outline general CAS principles seen not as *metaphors* that enrich another subject, but as directly applicable operational principles (Gell-Mann, 1994). It is this view of *cities themselves* as emergent, evolutionary systems that I wish to examine more closely.

Chettiparamb observes that research tying urban theory with CAS tends to follow two major approaches: quantitative work focusing upon modelling in computational environments (like that of Mike Batty and other computational geographers) or qualitative work that engages CAS as more of a metaphoric lens to highlight various urban processes (like that of David Byrne or John Urry). While both these approaches are fruitful, I wish to consider her call for a '*more detailed exploration of the abstracted features*,' and the need '*to detail out how the imported structural mapping plays out in the new target domain, thereby yielding new insights*' (Chettiparamb, 2006, page 82).

To this end I take as guides, firstly, the work of Evolutionary Economic Geographers (EEG), who apply CAS principles to the study of urban clusters, and secondly the work of Urban Morphologists who closely examine the material properties of cities. Finally, I look to understand the dynamics of complex systems based upon readings from a number of sources, too numerous to mention here (though outlined in Chapter Two). Amongst these sources, I would be remiss not to highlight the clear writings of the following individuals: Manuel DeLanda, who is able to navigate seamlessly between the hard sciences and the humanities; John Holland and Stuart Kaufmann (each of the Santa Fe Institute) who are able to explain complex processes in simple terms; and finally Francis Heylighen (Vrije Universiteit, Brussels), whose hundreds of publications on complexity provide a detailed synthesis of the mechanisms behind emergent phenomena and CAS dynamics. Each of these authors outline the fundamental principles of Complex Systems in an intuitive and concise manner, and it is largely through reading their works that I have developed an understanding of CAS principles. In what follows, I briefly discuss how each of these areas of research contribute to my central argument.

A   Evolutionary Economic Geography

Work in EEG, including that advanced by Ron Boschma and Koen Frenken (2005), as well as Ron Martin and Peter Sunley (2007b), aims to understand how the emergence of economic clusters can be seen as an outcome of Complex Adaptive Processes. Further, EEG follows the Santa Fe approach of using CAS principles in ways that are analogic as opposed to metaphoric. Accordingly, Evolutionary Economic Geographers frame their analysis of the behaviour of firms based on the premise that all CAS display general properties. They then attempt to graft the qualities derived from CAS systems onto the behaviours of firms, to thereby unpack the processes that lead to the emergence of economic clusters in the absence of top-down control. Here, firms are conceptualized as agents in a complex system that interact with one another and together manifest emergent properties.

This research adopts the perspective of General Darwinism, which argues that any system - biological or otherwise - involving mutation, selection, and retention of qualities will eventually evolve towards a more productive or 'fit' regime. Complex Systems Theory extends the framework offered by General Darwinian approaches to speak of multi-agent systems: ones wherein many agents work together to chart an overall evolutionary trajectory. These involve complex webs of interaction and non-linear feedback, leading to emergent phenomena. Emergence - the appearance of a global, unexpected broader pattern - while initially predicated upon bottom-up interactions, subsequently creates conditions of downward causation, whereby the agents within the system come to be constrained by the emergent entity.

The work of EEG is of particular interest because it pays attention to CAS dynamics that result in concrete formal consequences (in this case, clusters or 'agglomerations' of firms). Here, CAS dynamics are 'played out' on the ground, giving rise to new physical urban features, which in turn stabilize and reinforce their presence via feedback mechanisms. Two aspects of this perspective pertain to the research presented here: EEG engages CAS processes that unfold *in* physical space - rather than engaging CAS processes that *concern* physical space - and EEG assumes that behaviors of agglomerating firms are *examples* of CAS (rather than exhibiting metaphoric aspects of CAS).

B   Urban Evolutionary Morphology

The Ph.D. examines the relationship between CAS theory and urban morphological traits. By traits, I mean to say the physical components of urban design – streets, building plots, landmarks, street facades, etc, - that together form the material features of the urban environment (see Karl Kropf, 2011). Urban morphologists attempt to understand different inherent characteristics of urban form and unpack what kinds of forms give rise to positive urbanity. This thesis explores the hypothesis that certain kinds of urban morphological traits either inhibit or enhance the processes of complex adaptation as it occurs 'on the ground'.

Kevin Lynch provides fodder for morphologists by compartmentalizing the urban experience into *'imageable'* aspects of form – edges, landmarks, paths, districts, and nodes. His work is discussed at length in Chapter Six, where I argue that Lynch's work has been co-opted by the New Urbanism movement as a means to catalogue 'good' urban fabric (Ford, 1999; Hamer, 2000). But if New Urbanists aim to emulate the visual characteristics of 'good' urban fabric, we might also ask what makes fabric 'good' from a complexity perspective.

Here, I consider what makes certain fabric 'good' insofar as it enables certain kinds of processes – ones that support complex adaptation - to occur over the course of time. The work thereby builds upon

investigations of urban morphologists that aim to understand how the physical building blocks of urban space may or may not be conducive to promoting incremental urban change over time (see for example, Haken & Portugali, 2003; Hakim, 2007; Kropf, 2001; Marshall, 2008; Porta, et. al 2011). That said, while many morphologists consider the kinds of urban forms amenable to incremental evolution, few frame this understanding by explicitly engaging a CAS perspective (though there are some exceptions: see for example Hakim (2014)). The dissertation thus aims to contribute to urban morphological research by engaging principles of Complexity Theory in a more *explicit manner*: clarifying the mechanisms required for evolutionary change to occur.

C   Complexity Adaptive Systems Theory

Finally, the research aims to analyse urban fabric using a lens informed by CAS theory. To do so, a significant aspect of the dissertation involves outlining the principles of CAS theory in ways that make it applicable to urban processes. The thesis is that cities are not *like* complex systems, but rather that they *are* complex systems. I am indebted to research in complexity theory - particularly the work emanating from the Santa Fe Institute - that frames CAS as a meta-framework, the general principles of which can operate in many distinct areas.

Figure 1.1 illustrates how the Ph.D. work is situated in terms of the broader literature, with Complexity theory being a key influence, but the work of EEG and Urban Morphologists - who engage CAS theory - forming the research context.
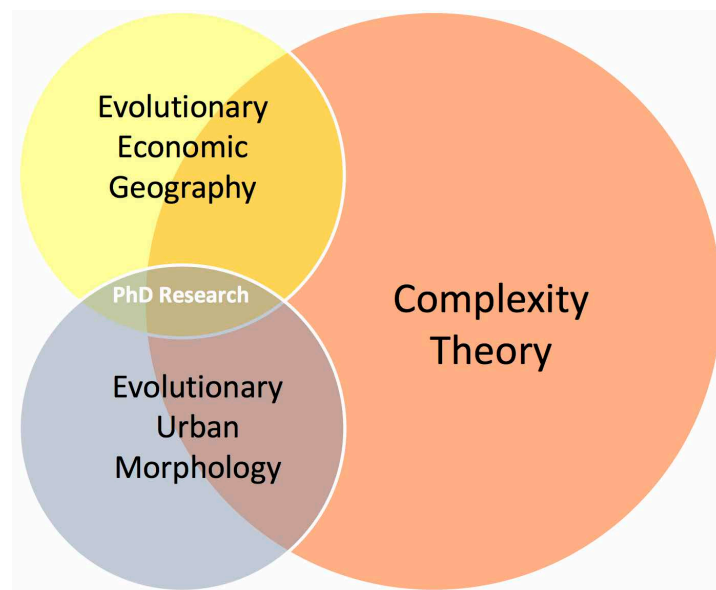
FIGURE 1.1 Positioning the Research

While this dissertation engages each of the three research areas above, it draws strategically from each, focusing upon:

— Adopting strategies developed within Evolutionary Economic Geography - which engages CAS as a non-metaphoric meta-framework - but enriching EEG with a more explicit material perspective (such that a discourse that already considers how the emergence of physical clusters is enabled by social,

economic, political perspectives is enriched by a theorization of the material conditions that might engender emergent outcomes).
- Considering evolutionary urban morphology through an explicit CAS 'lens' to read the efficacy of different kinds of formal characteristics. Here, the relevance of morphological characteristics is framed around how well these traits enable CAS dynamics to unfold.
- Engaging CAS in a non-metaphorical way - as a meta-framework that can be applied in numerous target domains in accordance with fundamental principles.

§ 1.3   Research Problem:

Until recently, the 'work' of urban design - from a practitioner standpoint - has been predicated upon the completion of master planning schemes: an approach that typically set goals and then attempts to impose a linear trajectory to achieve these goals. Here, *'city planners and the plans they produced assumed that cities were in equilibrium and the focus was almost entirely on implementing some form of blueprint depicting a desired end state'* (Batty & Marshall 2009, p.563, see Chapter Three). This approach to planning relied upon the predictive power of architects, transport engineers, and urban designers –those ultimately tasked with depicting the right kind of 'end state' for the cities we live in. Unfortunately, the predictive power of these actors was often lacking. This should not be seen as a critique of the rigour of the processes that were followed. Instead, the difficulty lies in the fact that cities are, as Horst Rittel would describe, 'wicked' problems - inherently complex, novel, un-testable, and unpredictable, (1973).

While there are certainly some instances of master-planned schemes that have proven successful, there have been more than enough that have proven disastrous. In particular, many of the mass housing schemes built in Europe and in 'regenerated' North American neighborhoods have proven to be uninhabitable. Apart from housing, many urban renewal schemes (involving new public plazas, or new 'signature' projects such as convention centers, sports facilities, or new market districts), often fail to produce the kinds of urban spin-off benefits they are intended to generate. Huge, publicly funded investments have, too often, failed to generate the benefits they were intended to create.

There have been a variety of responses to this lack of master-planning success. In some contexts, planners have moved away from a faith in the 'expert' vision, to instead call upon the public as a way to gain insight into actual rather than perceived needs. This has led to movements such as strategic and participatory planning (which draw insights from CAS theory). These approaches, while calling upon a greater number of voices and perspectives into the visioning conversation, nonetheless still assume the predictive power of these individuals as being accurate. Again, if we see urban problems as being 'wicked', such predictive power is suspect.

In the North American context where I work, formalist New Urbanist (NU) strategies (discussed in Chapter Six), offer another alternative to modernist techniques. This approach, which has garneered a huge following in North America both in practice and in academia, relies upon a proscribed, normative idea of urban 'goodness' based upon successful urban precedents. Rather than trying to predict what will work, the emphasis is on replicating what has worked in the past. While the physical settings created differ from those of modernist schemes, the method to achieve these settings nonetheless echoes previous modernist planning ideologies: basing itself upon a normative approach to decision-making which implies a singular and static version of truth. Far from invoking process, New Urbanists aim to create a static 'picture' of conviviality. This picture assumes a predeterminted and static

notion of what is 'good', without acknowledging the complexities and uncertainties of each particular urban environment.

Ultimately, the Ph.D .is concerned with how designers might generate 'good' urban form: the question is, what do we mean by good? I take the position that a significant aspect of 'goodness' relates to the urban fabric's capacity to easily evolve over time in response to shifting and uncertain forces (be they political, social, economic, etc.). This matters, because cities no longer have the time to evolve naturally over time. Those charged with 'making plans' have to make decisions, and too often they have both too little information to steer their decision-making, and too many factors of urban complexity to process. I am not alone in trying to address these concerns using a CAS framework. As I will outline in Part Two, computational modelers attempt to model complex factors by running multiple simulations; communicative and strategic planners try to gain greater insight into complex factors by running multiple consultation processes; and assemblage thinkers try to place the complexities of the city into a theoretical framework (though the ways in which this framework would assist in making decisions that would affect the urban remains unclear).

Notwithstanding this variety of approaches to engaging CAS and urbanism, while each of the discources above *relate* to the urban, none directly *engage* the urban. Is it possible that the urban fabric may, itself, possess (or be endowed with) the agency required to process urban complexity? Recent academic research in New Materialism (see, for example, Whatmore, 2006; Bennett, 2004; Delanda, 2004; Barad, 2003), places a renewed interest in the role that *matter* plays in activating situations. While the specifics of this particular discourse lies somewhat outside of the central scope of this dissertation, it nonetheless serves to highlight the concerns that I have with the typical approaches to urbanism that employ CAS: that is, the lack of engagement with material conditions in favor of other social, economic, political, or abstract considerations. With the retreat from drawing normative master-plans, also came a retreat from thinking deeply about the role the physical components of these plans might have in generating their own complex dynamics, or, as will be discussed in the thesis, responding to the complex dynamics that they are situated within.

What does it mean for form to respond? Here is where the questions of the thesis begin to become more focused: what are the ways in which physical elements, normally perceived as being static can, in some way, engage with and become an active part of the complexity of the city?

In answering this question, a complexity perspective to design would need to eschew notions of a singular equilibrium, recognizing instead that complex processes can unfold in multiple trajectories, with many possible end states, all of which are viable in different ways. In this conception, 'history matters' (or in more technical terms, is 'path dependent'), in that both planned and random fluctuations can result in entirely divergent (but equally viable) unfolding trajectories (DeLanda, 2000; O'Sullivan, 2004). A CAS ontology would thus concern itself not only with activating something in space and time, but in activating the possibility for many potential existences – creating circumstances whereby the *pluripotential* (de Roo and Rauws, 2012) of a region can be navigated in multiple, responsive ways.

A central thesis of this work is that the urban fabric can, in fact, be seen as a kind of phase space (Jones, 2009), that can be activated more or less effectively according to the morphological traits present therein. Activation involves increasing the number of 'degrees of freedom' that each urban artefact can manifest. This notion of degrees of freedom is not new – Delanda also speaks in these terms – but this work aims to clarify what this might mean in *concrete rather than metaphoric terms:* such that the material properties of physical urban fabric are directly implicated in the processes of CAS unfolding.

I wish, therefore, to consider what material factors would enable shifts in functional configurations: how a neighbourhood might shift from being predominantly office units to housing units; or a street might shift from car use to pedestrian use; or a bus route might shift from navigating along one trajectory to navigate along another. In each case, this shift would *emerge* from bottom-up CAS processes, without a predetermined outcome anticipated. At the same time I am interested in how we might design, from the outset, environments that are 'primed' or 'staged' so as to enable them to 'search' through various kinds of urban system states over the course of time and eventually, through feedback mechanisms, 'settle down' into a 'fit' functional state.

Here, as suggested by de Roo & Rauws, *'it is a matter of stimulating the diversity of development that link in with the current potential of the area. Embracing diversity, and therefore increasing flexibility and the possibilities for responding to uncertainties, [that] could create more opportunities for future innovations.'* (de Roo and Rauws, 2012, page 220). This perspective also involves accepting that the unfolding of any *particular* trajectory or development in space and time is but one of many *potential* (or 'virtual' as Deleuze would frame it), trajectories which – due to small shifts in initial conditions – might alternately unfold in completely different manners. Embracing this ontology requires a fundamental shift in typical practitioner thinking, such that design 'problems' are no longer seen as issues to be 'solved', but rather situations to be performed or enacted in ways that permit unexpected yet 'fit' solutions to emerge.

That said, there are many different kinds of productive or 'fit' urban conditions - each of which are culturally, politically, economically, and socially defined - and such conditions are often predicated upon human actors. Nonetheless, the material 'stuff' of urban fabric is not without a kind of enabling agency. Certain kinds of urban morphological settings can be more *responsive* to being altered by human agents in the face of broader forces. Here, we can speak of Gibson's theory of affordances, wherein certain artefacts *afford* broader ranges of action than others (Gibson, 1986).

This research, at the broadest level, therefore concerns itself with understanding the kinds of physical and material urban environments that have an enriched *capacity* to evolve. Here, when we think of capacity we include the 'phase space' of potential – a notion drawn from physics that is explored in depth in Chapter Five, *Considering how Morphological Traits of Urban Fabric Create Affordances for Complex Adaptation and Emergence*. Chapter five considers the notion of phase space (following Jones (2009)) which is more explicitly tied, in Chapter Eight, to Gibson's notion affordance (1986). Together, the concpets of Affordances and Phase Space help us frame how one might embed multiple performative capacities within a singular urban object, such that it can more flexibly respond to unfolding conditions in an adaptive manner.

§ 1.4   Research Tasks:

The Ph.D. argues that urban fabric, by being embedded with multiple affordances, can have an enhanced capacity to respond to changing urban forces. Accordingly, situated morphological features can, in a sense 'learn' how to operate in a more effective manner by having their affordances 'tested', enacted, or 'brought into being' as a response to shifting urban forces. The incremental evolution of these individual components eventually leads to emergent and 'fit' urban configurations.

An example of a 'fit' urban condition emerging as the result of an enabling material context can be found in the oft-cited case of pathways in a park. These pathways can be pre-planned (and they may or may not function well), or they can gradually emerge by means of many park-goers walking and leaving tracks in the grass – such that the areas with the greatest preponderance of foot-traffic become inscribed on the ground as functional pathways (which can thereafter be 'stabilized' through paving). Here the malleable affordance of the ground itself is a pre-condition for a 'fit' path emerging over the course of time through the actions of many actors.

That said, a given urban 'state' might be deemed 'fit' in accordance with many differing parameters, the metrics of which would be highly context dependent, and appropriate for each transformation. Thus, a functional shift from office to housing might be evaluated based upon lower vacancy rates or higher property values, a shift in road use might be accompanied by higher business traffic but more congestion, a shift in bus routing might result in higher average ridership and lower average travel times. The notion of 'fitness' is thus closely associated with the ability to steer the system with meaningful feedback (a concept explored in cybernetic studies) as well as information (the 'difference that makes a difference' according to Bateson (2002). Both of these notions are unpacked in greater depth in subsequent chapters.

Discovering a 'fit' state is a highly contingent process, with numerous possible outcomes, depending upon which parameters are activated. The research therefore neither presumes to predict the specificities of what ultimately evolves (an applied/predictive question that modelers of urban CAS often engage), nor offers any value judgements regarding what should ultimately unfold (a normative question that communicative planners often engage). Instead, it looks specifically at the necessary morphological prerequisites that can enable unfolding (an empirical question engaging explanatory variables).

The key **Research Question** is thus,

What physical and morphological conditions need to be in place within an urban environment in order for CAS dynamics to have an opportunity to arise - such that the physical components (or 'building blocks') of the urban environment have the capacity to discover functional configurations in space and time as a response to unfolding contextual conditions?

Answering this question hinges upon aligning key processes that occur within the source domain – Complex Adaptive Systems – to corresponding processes occurring in the target domain – Urban Environments. That said, if this reading is to be meaningful and robust, it requires a deep understanding and critical appropriation of CAS perspectives – an appropriation rigorously linked to actual CAS dynamics.

Accordingly, in what follows, I undertake the following **Research Tasks:**

A   *undertake a detailed examination of the key dynamics associated with complex adaptive systems that allow these to hold emergent, self-organizing and evolutionary capacity (regardless of the system under study);*

B   *identify the corresponding physical characteristics that need to be present within the urban morphological setting in order to instigate the unfolding of similar dynamics;*

C   *formulate and corroborate a clear analogical appropriation of CAS theory that illuminates the basic requisite requirements for physical urban environments to function as Complex Adaptive Systems.*

Finally, while understanding CAS is important, creating a vocabulary for this understanding that can be employed by the non-expert is key to making this understanding useful to a broader public of designers and planners. In order to bridge the theory of CAS phenomena with the methods and aspirations of urban designers, CAS needs to be conceptualized in a manner that makes it both accessible and functional. This results in the final research tasks:

D *develop a conceptual framework that makes the principles of urban CAS dynamics more understandable, intuitive, and operational for urban designers and planners;*

E *demonstrate how this formulation might be employed to steer design processes, whereby designers create 'potentialities' rather than designs, and steer or instigate - rather than control - dynamic urban processes.*

§ 1.5 Methodological Steps: chapter by chapter outline

Norbert Weiner was the first to use the term 'cybernetics' to refer to a new way of thinking about systems that are able to reach goals through adjusting trajectories in accordance with feedback (Wiener, 1948). The term cybernetics translates literally as 'steersman', coming from the Greek '*kubernan*' meaning 'to steer'. The steersman or 'oarsman' keeps his eye on the target and, through simple modifications to the oar's position, is able to reach his goal despite encountering complex forces of wind, currents, etc. While the oarsman can see his target, he does not know when he embarks on his journey the precise way he will need to maneuver the oar in order to reach it. Instead, he responds to the task at hand in real time and in accordance with feedback. Early cyberneticians believed that a broad range of seemingly divergent systems followed similar cybernetic principles, and undertook to undestand these principles.

In a similar vein, it is perhaps useful here to see this research unfolding not by means of a clearly charted path, but rather, like the topic itself, as a complex adaptive system. To put another way, it may be preferable to speak of a research 'journey' rather than a research 'methodology' (McGowan et al., 2014). Particularly when operating within complex domains, a clear methodological path may, while appearing rigorous, prove to be an artifice. A recent study asked researchers working on complex problems to describe their research trajectories. It yielded the following observation: '...*research journeys were [...] largely emergent or inadvertent; researchers adjusted their work according to the evolving question or emergent realities of the projects on which they worked.*' The authors continue, '*we must be more aware of the need for a [research] journey when approaching complex systems*', while maintaining '*an awareness of the researcher's relative position in the field, as an individual who does not uniquely observe but also interacts with and must react to the circumstances in which they find themselves*' (McGowan et al., 2014).

Similarly, I have initiated a range of research tasks and, according to feedback, I have adjusted my trajectory – reinforcing avenues that emerged as productive and abandoning tasks that yielded dead ends. Work developing Net-Logo models did not make its way into the dissertation and represents one such abandoned trajectory; work with students on speculative proposals was a late addition to the research (and may be said to have been a random exploration), yet this bore fruit. That said, throughout the years, I have maintained a clear target in mind that has steered my thinking: that is, to unravel how morphological traits of urban fabric might steer complex adaptation in urban environments. Like the oarsman in cybernetic thinking, I have kept my eye fixed on this target, while remaining responsive to various insights and inspirations along the way.

Accordingly, the methods employed to develop this research vary from task to task and paper to paper. In some instances, I examine case studies, compare literature, conduct site interviews, and examine historical documents. In others, I extrapolate principles from the work of others – particularly those working within the field of Evolutionary Economic Geography. Other work yet involves research by design, with this being undertaken through speculative competition entries and exploratory student research. Throughout, I employ a pragmatic approach that involves a combination of quantitative and qualitative methods. In each case, urban form is examined through the lens of complexity theory, attempting to derive how the built fabric may hold the capacity to evolve and exhibit emergent traits.

The unifying methodological thread has been to treat CAS dynamics as being applicable in multiple domains, position urbanism as one such domain, and then adopt inductive methods to illuminate how urban processes operate as CAS. A large part of the research task has, therefore, involved understanding the essential dynamics of CAS. This required examining definitions, principles, and a plethora of approaches drawn from a broad spectrum of literature dealing with complexity. That said, CAS is a still a young field, lacking clear boundaries, definitions, methods, and accepted terminology. Chapter Two of the Ph.D. attempts to synthesize the various key principles and approaches that inform complexity studies. It does so by casting a wide net, capturing sources from different discourses, with references from one discourse gradually leading a trail to another. With no accepted 'standard' model in place for framing CAS dynamics, I instead glean principles from research that is highly cited, and then proceed to identify the characteristics that help position how CAS dynamics are framed in order to better inform and understanding of urban cases.

I then elect to use case studies and illustrative examples as my primary means of grounding the research. The decision to use case studies and illustrative examples, rather than an experimental method, is due to the unwieldy scope of the urban case. There is no method that allows one to 'test out' urban morphological evolution and emergence within a scale and time-frame suited to Ph.D. research. Many researchers have addressed this constraint by employing computational models which 'simulate' urban unfolding. Early in my research, I made the decision not to pursue this method. This decision was based on a number of factors: an awareness of the conceptual limitation of models; the breadth of research already being pursued in this manner; and the fact that this research (largely undertaken within computational geography) was not transitioning easily into design practice. One of my key aims was to engage in research that would ultimately inform design practice and, therefore, I wanted to be able to point to specific morphological design principles that could intuitively be grasped by designers with reference to specific projects. This necessitated the need to move away from experimental methods that rely heavily upon code and abstract simulations: these remaining opaque to the majority of design practitioners.

Accordingly, the research is advanced primarily through the examination of different kinds of case studies. These fall under three categories. The first group of studies includes work conceived or built by others, in which the work's authors (or critical reviewers of the work) claim a theoretical link to complexity discourses. This is specifically the case with regards to the landscape urbanism projects that are highlighted early in the dissertation. In choosing the specific landscape projects to examine, I chose work that is both widely published and projects that, if built, I had personally visited. The second group of cases are those that remain in the form of speculative projects. These are chosen from work that I have had direct personal involvement in (built projects, competition work, or work undertaken by students enrolled in courses I teach). These examples, while mostly unbuilt, offer 'thought experiments' regarding the efficacy of employing CAS thinking in design. Each project sets out to specifically examine how CAS dynamics might inform new kinds of design strategies that could, in theory, steer complex processes leading to emergent urban form. Each aims to curate specific in situ urban conditions in ways that would allow these to better 'channel' the forces that steer complex

adaptation. They thereby employ research by design as a method and, as a body of work, begin to point to some common design approaches.

A third group of studies involves built work that, while not claiming an explicit link to complexity, appear to exemplify the properties of self-organizing and emergent conditions that I wish to foster. These include examples such as the canal houses in Amsterdam and the Grand Bazaar in Istanbul. The decision to focus specifically on the Grand Bazaar as the central case study was made for pragmatic purposes. The case stood out as an environment that appeared to rely upon a multitude of parallel agents acting independently whose actions, nonetheless, yielded an urban environment that exhibits emergent global properties. The behavior of the merchants operating within their respective spaces also appeared to echo CAS principles already being highlighted by Evolutionary Economic Geographers which I could, therefore, draw upon. Furthermore, engaging this site provided access to resources that allowed for more in-depth research to occur with relative ease. This included the availability of maps of the area which clearly document shifting emergent retail clusters, the ease of obtaining site interviews during the slow season when shop-keepers were personally available to be interviewed (and culturally open to discussing their practices during long conversations over tea), as well as the wealth of historical documentation on the Bazaar which provided a context through which I was able to understand traditional site practices.

Apart from these illustrative cases, I also chose to highlight New Urbanism methods – not so much as a case but as a counterpoint. This decision was made, in part, due to the impact that the New Urbanism is currently having in North America where I live and work. If this dissertation aims to consider how we might better structure urban fabric in order to channel emergent processes (and thereby yield 'fit' urban form), then New Urbanism is about proscribing 'fit' urban forms in an attempt to stimulate better urban processes. Clearly, New Urbanists are interested in the power of urban morphology, but they see this power as pertaining to what the form *looks like*, whereas this research aims to understand what form *does*.

The various sections of the dissertation thus engage a multifaceted (complex!) approach to research that incorporates inductive logic, comparative analysis, and case study research to pull from different threads of inquiry so as to achieve my target goal, to: ***develop an understanding of key morphological features of urban environments that enable CAS unfolding.***

In order to achieve this, I ultimately pursue the following methodological steps:

1   Identify key overarching CAS properties
2   Situate the research within existing key literature
3   Consider relevant urban precedents
4   Generate a hypothesis for viewing morphological traits as enabling CAS dynamics
5   Develop a conceptual framework for relating urban traits to CAS dynamics (based on hypothesis)
6   Test/Corroborate the hypothesis through case study work informed by existing research
7   Speculate on future research directions given emerging technologies

The following section of the Introduction discusses in greater detail how each chapter of the dissertation contributes to the methodological steps discussed above:

First: identify key overarching CAS properties: The nature of CAS dynamics is discussed in each of the chapters, but is most thoroughly reviewed in **Chapter Two**, '*Research In Urbanism And Planning drawing from Complex Adaptive Systems Theory: Divergent definitions, concepts, methodologies, and trends*'. This Chapter begins with an overview of CAS properties, and how these properties have been

incorporated into urban planning and design. It provides a comprehensive literature review of the state of the field. The article begins by looking at the various definitions of Complex Adaptive Systems that have been highly cited over the course of the last five decades. It then traces the crossovers between these definitions in order to formulate a working synthesis definition of CAS. This definition highlights six 'traits' of CAS that appear to be ubiquitous, in that CAS are:

— Adaptive, evolutionary, and rule-based;
— Comprised of a diversity of agents;
— Described by scale free/nested mathematical hierarchies;
— Characterized by self-organizing and fit emergent features;
— Organized through flows and interactions;
— Subject to non-linear, far from equilibrium and historical processes.

Using these headings, I position various key concepts and thinkers within these six traits [Figure 1.2].
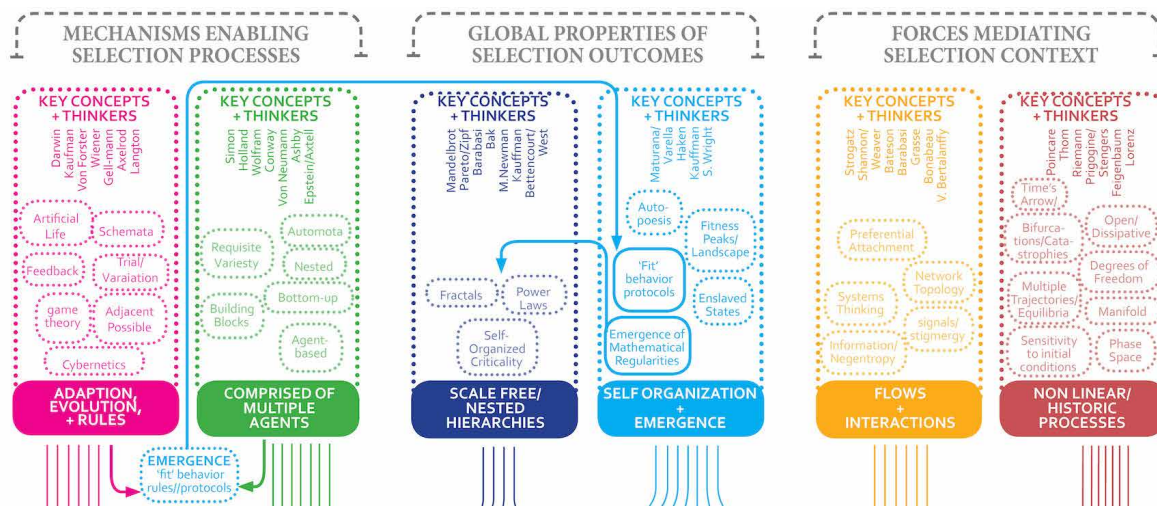
FIGURE 1.2 Principles of Complex Adaptive Systems

Having categorized the characteristics of CAS in this way, they can then be grouped into three overarching classes: mechanisms that enable selection processes, properties of the selection outcomes, and forces mediating the selection context [Figure 1.3]. These classes of CAS dynamics are used to outline the general meta-principles of Complex Systems. The various features or CAS processes that are identified and discussed are derived from a careful reading of the associated scientific research, including both secondary sources and various works of the primary authors cited.

Second: situate the research within existing key literature. There is a wealth of urban research that engages complexity, but each treats it differently - tending to be centred upon only a certain number of the relevant traits. This then affects how CAS is defined, which authors are cited, and which properties are deemed useful to consider from an urban perspective. I partition the existing research into CAS dynamics into an array of key research 'streams' each of which draws from CAS theory in different ways, with different emphasis and often different sources. I discuss eleven different streams of urban research that each draw selectively from different aspects of CAS theory [Figure 1.4]. These

cover a spectrum of research that includes computational geography, parametric urbanism, relational geography, assemblage geography, urban morphology and evolutionary economic geography (see for example Batty, 2007; Healey, 2007; Portugali, Meyer, Stolk, & Tan, 2012; Urry, 2003).

FIGURE 1.3 Classes of CAS Dynamics

MECHANISMS ENABLING SELECTION PROCESSES

GLOBAL PROPERTIES OF SELECTION OUTCOMES

FORCES MEDIATING SELECTION CONTEXT

KEY CONCEPTS + THINKERS

Darwin
Kauffman
Von Forster
Wiener
Gell-mann
Axelrod
Langton

Artificial Life
Schemata
Feedback
Trial/Variaiation
game theory
Adjacent Possible
Cybernetics

ADAPTIVE & EVOLUTIONARY RULE BASED

KEY CONCEPTS + THINKERS

Simon
Holland
Wolfram
Conway
Von Neumann
Ashby
Epstein/Axtell

Requisite Variety
Automota
Building Blocks
Nested
Bottom-up
Agent-based

COMPRISED OF A VARIETY OF AGENTS

EMERGENCE 'fit' behavior rules//protocols

KEY CONCEPTS + THINKERS

Mandelbrot
Pareto/Zipf
Barabasi
Bak
M.Newman
Kauffman
Bettencourt/West

Fractals
Power Laws
Self-Organized Criticality

SCALE FREE HIERARCHIES

KEY CONCEPTS + THINKERS

Maturana/Varela
Haken
Kauffman
S. Wright

Auto-poesis
Fitness Peaks/Landscape
'Fit' behavior protocols
Enslaved States
Emergence of Mathematical Regularities

SELF-ORGANIZING & EMERGENT GLOBAL PROPERTIES

KEY CONCEPTS + THINKERS

Strogatz
Shannon/Weaver
Bateson
Barabasi
Grasse
Bonabeau
V. Bertalanffy

Preferential Attachment
Systems Thinking
Network Topology
Information/Negentropy
signals/stigmergy

ORGANIZED BY FLOWS & INTERACTIONS

KEY CONCEPTS + THINKERS

Poincare
Thom
Rieman n
Prigogine
Stengers
Feigenbaum
Lorenz

Time's Arrow
Bifurca-tions/Cata-strophies
Open/Dissipative
Multiple Trajectories/Equilibria
Degrees of Freedom
Sensitivity to initial conditions
Manifold
Phase Space

SUBJECT TO NON-LINEAR & HISTORIC PROCESSES

URBANISM + PLANNING ASSOCIATIONS/APPROPRIATIONS:

BOTTOM-UP / TESTING/PROTOTYPING / ITERATIVE	RULE-BASED / ITERATIONS / EVOLVING / FEEDBACK LOOPS / BOTTOM-UP ELEMENTS / NO CENTRAL CONTROL / UNIT BASED / TENDS TOWARD FRACTAL / SELF-SIMILIARITY / 'FIT' BUILDING BLOCKS	FEEDBACK LOOPS / RULE BASED / ITERATIONS / ELEMENTS / MODULAR / LARGE NUMBER / BOTTOM-UP / FRACTAL PATTERNS / FIT BUILDING BLOCKS/RULES / COHESIVE URBAN PATTERNS	SIMPLE RULES / FEEDBACK LOOPS / ITERATIONS / VARIABLES / BUILDING BLOCKS / MATHEMATICA / FIT SCHEMA / ATTRACTOR STATES / DYNAMIC INTERACTIONS / BIFURCATIONS / MULTIPLE SCENARIOS	FEEDBACK LOOPS / RULE-BASED / LARGE NUMBER OF AGENTS / FIRM RULES/PROTOCOLS / PREFERENTIAL ATTACHMENT / FLOW OF ENERGY / LOCAL INTERACTIONS / PATH DEPENDENT / NON-LINEAR	FEEDBACK LOOPS / FIT CONFIGURATIONS / CONTAINING TOWNS / UNFOLDS VIA INTERACTION / OPEN SCAFFOLDS / INDETERMINANT SPACE / UNFOLDING OVER TIME / AFFORDANCES	BOTTOM UP / DIVERSITY OF AGENTS / CONSENSUS / DYNAMIC INTERACTION / INTERDEPENDENCE / MULTIPLE EQUILIBRIA / BIFURCATIONS	REDUNDANCY / NESTED HIERARCHIES / MULTIPLE EQUILIBRIA / SAFE TO FAIL	AGENCEMENT / STABILIZED ASSEMBLAGES / RHIZOMES / HISTORY / CONTINGENCY / MANIFOLD / "THE VIRTUAL"	PATTERNS OF INTERACTION / NETWORK TOPOLOGY / FLUIDITY/MOBILITY / RELATIONS BETWEEN / OPEN DISSIPATIVE
TACTICAL URBANISM	**INCREMENTAL URBANISM** (morphology based)	**URBAN INFORMALITIES**	**URBAN COMPUTATIONAL MODELING**	**EVOLUTIONARY ECONOMIC GEOGRAPHY**	**LANDSCAPE URBANISM**	**COMMUNICATIVE PLANNING**	**RESILIENT URBANISM**	**ASSEMBLAGE GEOGRAPHY** / **RELATIONAL GEOGRAPHY**

Lydon
Garcia
Stealth
S v.d. Beek

Habraken
Salingaros
Porta
Schneider/Till
Marshall
Portugali
Siksna

Cannigia
Conzen
Muratori
Alexander
Jacobs

Ben Hamouche
Hakim
Araveno
Dovey
Mcfarlane

Rudofsky

Batty
Benenson
Torrens
Pumain
Allen
Tom Evans

Schelling
Ulam

Boschma
Martin
Sunley
Sheppard
Franken
Yeung

Hayek

Koolhaas
Waldheim
Corner
Stan Allen
Rietveld/Rietveld
Belanger
Prominski

McHarg

Healey
Innes/Booher

Habermas

Brand
Ahern
Pickett
Fernandez

Ignacio Farias
Jean Hillier
Jason Dittmer
Kim Dovey
McFarlane/Anderson
John Protevi

Deleuze/Guattari
Delanda

Ole Jensen
Amin/Thrift
John Urry
Massey

Latour
Castells

complementary influences

FIGURE 1.4 Streams of Urban research drawing from CAS principles

Third: learn from relevant urban precedents: Having discussed the various ways in which different streams of urban research draw from CAS principles, I note that few of these streams focus upon the material features of the built environment: that is to say, how complex urban dynamics unfold in situ. While there is some urban work occurring that is highly relevant from this perspective, it is seldom situated as part of the dominant planning literature. Chapters Three and Four therefore highlight two existing urban intervention strategies, Landscape Urbanism (Chapter Three) and Tactical Urbanism (Chapter Four), that are analysed with reference to how each embody certain CAS dynamics.

Chapter Three, *'Situating Complexity in Contemporary Landscape Practice',* argues that the Landscape Urbanism movement (LU) integrates the vocabulary and concepts of CAS within its design rhetoric. LU theorists speak of creating 'open scaffolds' that generate 'possibilities' and invite appropriations (Corner, 1999b; Waldheim, 2006). I argue that such approaches resonate closely with CAS theory, and that insights from these projects can meaningfully point to how CAS processes might be manifested on the ground. I then compare the key attributes of CAS (as derived in Chapter Two), with key LU Strategies to show the similarities in conceptual approach [see **Table 1.1**]).

CAS Characteristics	Landscape Urbanism Strategies	Traditional Planning
Adaptive and evolutionary	Create catalyzing environments that adapt to unknown futures	Master plans, fixed outcomes, static.
Described by scale free/nested mathematical hierarchies	Develop overlapping, interacting, organizational hierarchies	Single compositional plane of elements
Organized through flows and interactions.	Leverage infrastructure and flows	Built physical 'objects' organize and generate relationships
Subject to non-linear and historical processes	Allow for non-linear, open-ended, and contingent transformations over time	Optimized for planned/known outcome
Characterized by self-organizing & emergent behaviours	Foster process-driven, emergent outcomes	Characterized by fixed/static patterns
Comprised of a diversity of agents	Activate bottom-up tactics and strategies to generate use	Implemented through top down control.

TABLE 1.1 Landscape Urbanism strategies compared to CAS and traditional planning practices

Despite these clear resonances, the examples of LU practice is still in early stages, with its conceptual ambitions not fully realized in practice. A survey of various LU projects points to the gap between key LU project's claimed objectives and how these are actualized to a greater or lesser degree. I argue that further work is needed for the reality of the projects to more closely align with the rhetoric employed.

Accordingly, I look to a second precedent - that of Tactical Urbanism (TU) - as another instance of urban intervention that might inform CAS. TU employs provisional testing, feedback, and the exploration of urban phase space in an incremental, fluid manner. **Chapter Four**, *'Tactical Urbanism as a means of testing relational processes in space: A Complex Systems Perspective'* (Planning Theory, 2017), argues that tactical urban approaches - ones that leverage the power of incremental exploration, as well as evolutionary adaptation - provide an important precedent for how complex urban processes might *unfold* on the ground. Further, the article presents a speculative design competition entry (which I helped develop), that specifically engages CAS and evolutionary processes through tactical means. While Tactical Urbanism is not generally theorized through a CAS lens, by means of this example I demonstrate that it nonetheless exemplifies processes central to CAS – incremental testing, feedback and evolution [see **Figure 1.5**]. I argue that, deployed intentionally, TU strategies point to a new way of engaging with contingency in planning, offering a kind of, *'engine of complexity' (Marshall 2012, p.191)*
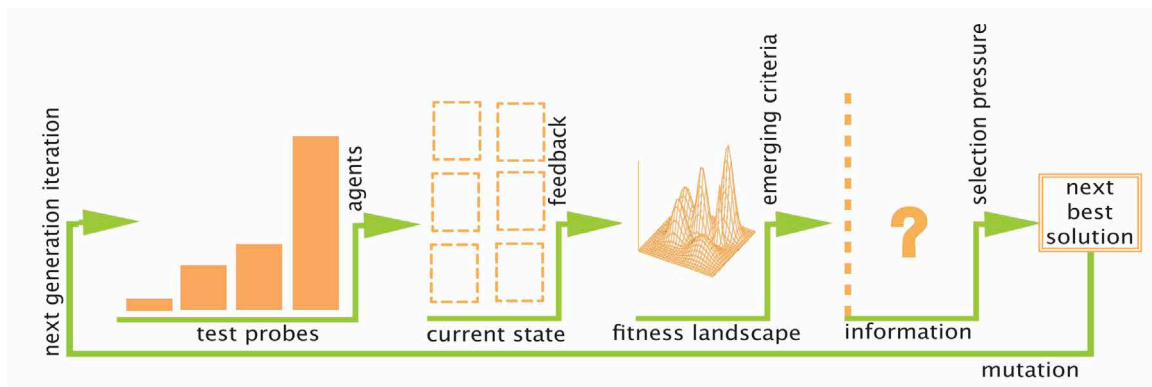
FIGURE 1.5 Tactical Urbanism Processes

While both LU and TU provide precedents regarding how various urban approaches do in fact employ aspects of complexity 'on the ground', I note that these approaches are only weakly theorized through the lens of Complexity Theory.

Fourth: via inductive logic, generate a hypothesis for viewing morphological traits as enabling CAS dynamics: Following from the consideration of TU and LU approaches as material precedents for leveraging CAS processes, I then use inductive methods to consider what sorts of qualities the physical environment needs to embody in order for complex dynamics to be supported. **Chapter Five** *'Considering how morphological traits of urban fabric create affordances for Complex Adaptation and Emergence'*, (Progress and Human Geography 2016) defines with greater specificity how one might identify and quantify the kinds of morphological characteristics of space that are germane to CAS processes.

The chapter provides a broad overview of why the qualities and traits of morphological space might matter insofar as CAS dynamics are concerned. It makes the case that while EEG considers many political, social, and economic aspects of why certain kinds of firms tend to cluster - leading to 'emergent' districts - there is little theorizing on the role that morphological qualities of space play in steering these dynamics. It argues that this is a missing dimension in EEG's analysis of CAS - one pertaining to physical traits - and begins to conceptualize what kinds of traits matter.

Part IV of this chapter, under the heading *'Urban Features that support the support the exploration of spatial trajectories'*, suggests the kinds of traits required for physical setting to perform in a manner analogous to Complex Systems. It carefully examines the following specific aspects of the urban environment, to show how these relate to requisite dynamics within Complex Systems:

— Spatial cells as agents;
— Minimum functional size, parallel iterations, multiple functional states;
— Signals, stigmergy and information;
— Aggregations and emergence.

Again, this examination draws explicitly from the procedural formality of CAS as understood in the sciences. Here, the correct unit of analysis within urban systems is deemed to be the most ubiquitous 'chunk' of urban fabric (what I refer to as the 'urban cell'), which is then analysed to determine the number of 'states' it can easily manifest as. The article suggests that instead of aiming to design

'optimized' urban entities, there may be benefits in designing environments such that the urban fabric might easily be appropriated in multiple ways – manifesting in different 'states'.

These differing states are conceptualized with reference to Gibson's (1986) theory of 'affordances'. The notion of affordance suggests that an artefact can be designed in a manner that invites it to be appropriated in multiple ways. This then implies a specific way of engaging urban design where, instead of seeking single, optimum solutions, design would involve creating material conditions that have the capacity to respond to unknowable site forces – urban *affordances* instead of urban designs that can unfold in multiple potential trajectories, or positions in *phase space*.

I carefully examine this concept of 'Phase Space', which follows from work advanced by Martin Jones (2009). Jones argues that different kinds of contexts can either expand or limit the capacities of phase space. This perspective resonates strongly with Gibson's 'space of affordance', where material objects can in a sense 'enable' different kinds of appropriations. I take further cues from DeLanda (2005), who observes that different entities have different kinds of *capacities* (which remain virtual until they are activated), but nonetheless remain part of an entity even if never manifested. Dittmer (2014), following DeLanda, speaks about the particular significance of *material* capacities and how these might help structure 'possibility spaces'. As material entities enter into specific kinds of relationships with other entities (as assemblages) their particular capacities are (contingently) actualized. This section explicitly codifies what we mean by 'increasing the phase space of possibilities', where the total number of cells and the total number of states, begin to map out the potential degrees of freedom or the 'phase space' of the system (Frenken et al., 1999).

Next, I consider how searching this space of possibilities for optimum configurations is more optimally achieved in systems that employ a large number of agents and the presence of information signals that help steer system trajectories. I discuss the importance of parallel search, and also the critical need for *stigmergic* signals (information tags made tangible within the shared environment of agents), to steer the system (Heylighen, 2011b). Over time, feedback from multiple search in tandem with stigmergic signals begins to limit the degrees of freedom within any given context - such that emergent patterns manifest and are 'enslaved' (see also Haken & Portugali, 2003).

The chapter also touches upon issues surrounding agency. Clearly, typical urban artefacts are incapable of directly 'sensing' the environmental signals necessary to steer evolution and are equally incapable of autonomously changing their state. I thus discuss the imbricated role of human agents, who form part of the system, but whose actions are also constrained and directed by the material properties of the physical environment. Here, I argue that material agency is 'entangled' and 'imbricated' with human agency (Pickering, 1993; Schatzki, 2005).

Fifth: develop a conceptual Framework for relating Urban morphological traits to CAS dynamics: The central hypothesis of Chapter Five is that the physical traits of form are not neutral, but instead have specific performative capacities that enable complex processes to unfold. **Chapter Six,** '*From Form to Process: Re-conceptualizing Lynch in Light of Complexity Theory*' (Urban Design International, 2017), takes the theoretical principles outlined in Chapter Five, and tries to make these more tangible. To this end, Chapter Six introduces a practical framework for discussing how CAS processes might be categorized and identified, providing tools for analysing and conceptualizing urban formal dynamics. Thus, while Chapter Five outlines key dynamics, Chapter Six makes these dynamics more clearly analogous and intuitive with regards to urban design.

To achieve this end, the widely accepted urban categories defined by Kevin Lynch – Edges, Paths, Districts, Landmarks, and Nodes – while normally used to think about urban *objects,* are here

appropriated to discuss various critical CAS *processes*. This co-opting of Lynch is purely pragmatic. Re-purposing an existing framework avoids the confusion created by an over-proliferation of 'models' that constantly introduce new terms or categories into the design and planning discourse. Lynch's framework is already familiar and intuitive to all and can, therefore, serve as a useful bridge for engaging concepts that are entirely unfamiliar **[Figure 1.6]**. The use of Lynch's terms is intended to make the engagement with complexity more accessible to practitioners – something that has been made difficult by the sense that CAS perspectives reside within the specialized confines of computer modellers[1] or urban geographers.[2]

Principles of Urban Design

CONCEPTUAL BRIDGE (Kevin Lynch's Classification System)

Principles of Complexity Dynamics
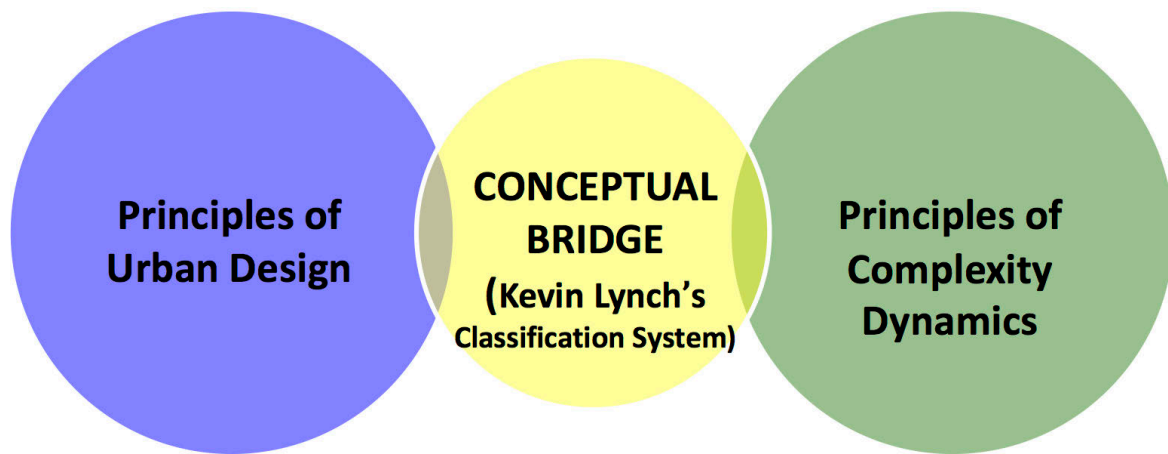
FIGURE 1.6 Translating CAS for Practitioners

Sixth: test /corroborate conceptual framework: The efficacy of the Lynchian framework is put to the test as an analytical tool in Chapter Seven. Simultaneously, the framework's usefulness is corroborated with reference to theorizing developed within the field of Evolutionary Economic Geography. **Chapter Seven**, *'The Grand Bazaar in Istanbul: The Emergent Unfolding of a Complex Adaptive System'* (International Journal of Islamic Architecture, 2015), provides a test case for the efficacy of the conceptual framework. The article examines the Grand Bazaar, hypothesizing that the emergence of specific trade areas within that district can be viewed as an example of CAS dynamics at play in the urban realm.

In order to situate this analysis, I turn to Evolutionary Economic Geography (EEG). EEG researchers, like many other geographers, attempt to draw insights by looking to Complexity Theory. However, unlike most geographers, their work is heavily informed by what occurs in real time in on the ground

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[1]   This assertion is based upon experience in practice, but a quick corroboration is found by looking at two key Urban Design journals – the Journal of Urban Design and Urban Design International. Mike Batty's seminal work on computational modelling is not included in either of these publications, and the work is barely cited., A search for the key phrase 'computational geography' yields only three articles in both J of UD and UDI; similarly, the phrase 'computational modelling' yields only six results in J of UD and a slightly better eight in UDI.

[2]   The highly conceptual and theoretical nature of complexity research in Urban Geography renders this discourse largely inaccessible to the vast majority of urban design practitioners. By contrast, it is partially due to New Urbanism' 'accessible' nature that it has been so widely embraced by the same audience.

specific cases. Having introduced the work of EEG in Chapter Five, it is now re-introduced and employed as a reference/corroboration tool in Chapter Seven.

EEG scholars endeavour to examine the fundamental nature of CAS dynamics, where they appropriate an understanding of fundamental CAS dynamics from that source domain to help understand the dynamics of emergent economic clusters (their target domain). This line of analogic thinking uses CAS principles to unpack the bottom-up mechanisms that facilitate the agglomeration and clustering of similar kinds of firms into particular regions (Silicon Valley, for example). Their research also draws heavily from General Darwinism - considering this framework to be useful in understanding a broad range of evolutionary and emergent dynamics – which go far beyond those found in biological domains (Beinhocker, 2011; Hodgson and Knudsen, 2006).

EEG draws analogies by considering the notion of 'the firm' as analogous with 'the agent' in CAS. Here, flows between firms - manifested as flows of personnel or goods – behave as mechanisms that support information transfer. EEG goes on to demonstrate how combinations of different kinds of knowledge transfers (local buzz and global pipelines), need to be in place in order for the successful emergence of productive business clusters to occur (Bathelt et al., 2004a). In this way, EEG works to 'decode' CAS phenomena and make them tangible and specific when speaking about emergent economic activities - employing a rigorous analogic appropriation of CAS dynamics to understand the corresponding cultural and economic dynamics that facilitate instances of economic clustering.

The analysis of the Grand Bazaar attempts to expand upon EEG research by incorporating a more explicit *material* dimension to the kinds of processes that EEG examines. That is to say, while EEG attunes to the economic, cultural, and political processes that steer the evolution of economic activities unfolding *within* space, the physical structure *of space itself* typically remains outside of the scope of their discussion. Here, the role urban form might play as an enabler - or alternatively as an inhibitor - of CAS dynamics remains unexplored within this literature. Chapter Seven, therefore, examines how 'material artefacts' that make up the urban fabric, might '*restrict, constrain, contain and connect the mobility of relational things' (Jones, 2009: 496)* By doing so, it responds in part to comments by EEG theorists Martin and Sunley, who note 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: 584–5)

Notwithstanding this limitation, EEG research does demonstrate how one can consider the dynamic functional unfolding of an urban environment in a manner that is analogous to that which occurs in a complex system. It thus offers an important departure point for my investigation - a kind of 'barometer' (or benchmark) with which to compare and corroborate my thesis. Here, I follow up upon the comparisons made in Chapter Six, where I attempt to formulate such questions as: what does an 'agent' mean in an urban environment; what form does 'energy' take in such contexts;[3] what do we mean by 'information' and how is information, stored, relayed, and acted upon within the context of an urban setting?

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[3] The term 'energy' is used here to describe whatever relevant parameter controls the number of potential system states. This corresponds with the 'x' axis on a bifurcation diagram (see also Reed & Harvey, 1992 for more on the role of energy input in CAS).

To answer these questions, the article analyses the bazaar's material characteristics by employing the Lynchian framework to consider various physical traits of the urban environment including: *scale* (urban grain); *information* (urban edge); *flows* (urban paths); and the presence of global and local *hubs* (landmarks and nodes). It then considers how these urban components, acting in tandem, enable complex processes to be manifested such that emergent retail clusters (districts) appear in the absence of top-down control. The paper argues that:

A   The presence of multiple, fine grained shops (urban *cells*) establishes the requisite variety for transformation and exploration;

B   The redundancy of street networks (*paths*) supports highly flexible channelling of flows;

C   The presence of particular urban junctures (*hubs*) - both local *nodes* and global *landmarks*- facilitates information transfer, the maintenance of stable routines, and the testing of novel synergies;

D   The clarity, visibility, and redundancy of street transactions (urban *edges*), supports information transfer; and

E   Taken together, the dynamic interplay of these urban components allows for the emergence of functional, emergent *districts* of distinct market goods.

MODIFIED LYNCHIAN URBAN FRAMEWORK		
Physical Features	**Functional Role in CAS**	**Ecosystem Examples**
Cells: Typical Grain of Urban Fabric (shops/homes/etc.).	Parallel agents working to maximize resource use.	Species (birds, insects, fish).
Paths Street Networks	Network links facilitating flows of resources, information and energy entering the system and connecting agents across space.	Channels of energy sources flowing through an environment (streams, sun-paths, soil nutrients, foraging trails).
Hubs (Landmaks and Nodes) Gathering places (public plazas, churches, schools, squares, etc.).	Juntions within networks where resource flows converge and concentrate. Occurs at both global and local scales. Sites of least energetci resistance.	Congregation sites where flows converge (nests, ant hills, dens, etc.). Areas with high densities of resources - food/fuel source sites (ponds, nutrient pools, fruiting plants, etc.). Basins of attraction.
Edges [1] Urban surfaces, public/private interfaces (streetfront displays, hard or soft surfaces).	Tags signifying agent competencies, steering resources towards agents that can best process them. Broadcasts successful and unsuccessful agent strategies.	Signals broadcasting information to other species (pheromone trails, bird calls, plumage displays, etc.).
Districts Complimentary use zones or clustered use areas (antique districts, gallery precincts, etc.).	Aggregations of co-evolved agents that efficiently circulate resources	Patches of species inhabiting a parciular niche (schools of fish, flocks of birds).

TABLE 1.2 Adopting a Lynchian tool-kit for analysing CAS processes.
Note [1]: Lynch originally used the term 'edge' to refer to district boundaries, rather than building surfaces

Seventh: speculate on future implications given emerging technologies: Chapters Eight and Nine of the dissertation begins to speculate about future research directions, showing how a CAS informed ontology for thinking about urbanism can be employed in a variety of novel ways. Here, I focus upon urban processes that are steered or enhanced by means of virtual interfaces: apps or sensors that support the spread of meaningful signals within the urban evolutionary context.

Chapter Eight, '*Conceptualizing urban infrastructures as 'smart', decomposable, and information-processing agents*', discusses how urban artefacts can be designed as computational devices that have the capacity to 'evolve' in real time, in situ, in response to information feedback that they receive from the physical environment they are situated within. This research was developed in tandem with students who attended a Graduate Seminar course on Complexity (which I have taught for three years in the College of Design at Iowa State University). A series of student projects illustrate how urban

artefacts can be re-conceptualized as evolving agents through embracing a CAS perspective to urban phenomena.

This research involves: identifying the nature of urban agents involved; the nature of flows or information signalling; the parameter (or energy) that 'drives' the solution state; how the 'space of possibilities' is gradually constrained in accordance with feedback; and how a particular state ultimately emerges. In each case, the design of the physical environment is mediated through digital tools that help carry 'signals' or information about how the urban situation might evolve. This is an extension of the notion of stigmergy introduced earlier in the dissertation (see also Heylighen, 2015), where I note that CAS require ways in which agents can transfer information to one another to help constrain and direct evolutionary behaviour, and that this information can be stored in a common medium shared by all agents.

The article argues that the student's speculative projects demonstrate how the dynamics that normally are associated with computer simulations using agent based or cellular automata rules, can instead be transposed into physical settings. Here, material artefacts are conceptualized as distributed 'information processors', that process inputs coming from their environment, and respond by shifting their augmented performative capacities so as to yield emergent, global urban outcomes. The principles of these dynamics echo those discussed in the Grand Bazaar, but here the dynamics are enriched or 'augmented' by means of 'smart' capacities that increase the fluidity and fidelity of information transfer between both the system agents and the environment they reside within.

Chapter Nine, *'Sensing the City: Legibility in the context of mediated spatial terrains'* (Space and Culture, accepted subject to minor revisions) discusses future research directions where dynamics occurring in virtual space might mediate the way urban experiences unfold in physical space. Here, I reflect upon how the growing ubiquity of mobile phones and apps, and their capacity to support and spread information about the urban environment through the signals they help propagate, allowing for new kinds of planning and interventions strategies. Given that *information* is key to enabling Complex Systems to evolve, the ubiquity of information transfer made possible via web interfaces can be employed to help steer physical systems. Thus, while the built environment can at times store and transfer information (through 'signals' like storefront windows that reveal product lines), digital interfaces can *amplify* and propagate these signals with greater ease, allowing strong patterns to emerge.

This article once again reflects upon Lynch, by considering how traditional forms of urban 'legibility' are being challenged by virtual signals that create new kinds of virtual markers – even if these are not tangible through the traditional senses. Signals can come to be amplified in ways that create new kinds of order by means of bottom-up user-specified criteria for navigating the 'space of possibility' of the city.

§ 1.6   Research Limits

This Ph.D. primarily investigates how particular morphological traits of urban form may be analysed through a CAS lens, and to consider how these forms might enable, or 'create affordances' for CAS dynamics to unfold. At the same time, the research develops a set of analytical tools that can be used to 'unpack' various urban morphological conditions through the lens of CAS.

Whether or not this lens provides an accurate insight into the actual dynamics in play remains somewhat speculative. I have set up a form of analysis, and then I have endeavoured to find 'proof' (in various case studies) of the dynamics I believe to be in play. This search is therefore not neutral, and there remains the possibility that I am reading into situations the dynamics that I wish to find. In order to mitigate this risk as much as possible, I have attempted to corroborate the findings by showing how the features that are highlighted within this investigation echo those that EEG researchers trace and would also seem to closely parallel the kinds of dynamics we see in complex systems. Further, in the 'Future Directions' portion of the work, I demonstrate how the reading of emergent urban phenomena as a kind of information processing system can be used as a problem-solving mechanism with which to re-frame a host of urban issues.

A further limitation pertains to what kinds of 'results' we see from self-organizing systems. I have not endeavoured to critique the *values* associated with outcomes of this approach in addressing urban situations. While a bottom-up emergent perspective may provide a new way of engaging urban problems, this is not to say that this will always be the best way, nor that the emergent solutions would necessarily be better than those derived by other means. Indeed, one might argue that emergent systems may result in an exacerbation of parochial behaviours – where 'niches of interest – develop that stifle exchange and civility. While I believe that providing a CAS perspective to problem-solving can be a useful alternative to other methods, I do not make claims that this is the only method nor, in all situations, the preferred method. However, I do state that the outcomes of CAS processes would seem to hold promise by offering certain features that could be deemed beneficial – resiliency in the face of perturbation being a key example.

Given the breadth of Urban Design as a research domain, the research is necessarily limited by the fact that it is impossible within the scope of a Ph.D. to create, from scratch, a physical test case of a complex adaptive emergent urban environment in a real-world setting. Complex systems, by their very nature, take time to evolve, and both the scale and the time frame involved in urban unfolding goes well beyond the framework that Ph.D. research might hope to engage. In the absence of a true control sample, the factors being considered are necessarily muddied.

In response to these limitations, I have employed three tactics: The first is to examine Case Studies that I believe exemplify the kinds of morphological unfolding that I wish to engage. These examples, including that of Tactical Urbanism and Landscape Urbanist strategies, are used to demonstrate that non-deterministic planning strategies are possible. I then unpack how these examples can be theorized from a CAS perspective. Secondly, I look at real world examples of urban environments that have emerged over time, most specifically the Grand Bazaar in Istanbul, and evaluate whether or not the CAS analytical framework that I develop can be used to analyse such urban cases that have exhibited self-organizing and emergent phenomena. Finally, I provide a series of speculative design propositions – both those that I have generated in competition entries and others that have been conceived by my graduate students. These provide further cases of how a CAS perspective might meaningfully be employed in the design of built environments. By using these three tactics in tandem I seek to build an argument that taking a CAS perspective to analyse the material condition of the urban environment is possible, and that the framework that I provide to enable this approach is both useful and productive.

Primarily my aim is to provide a new lens that permits new issues to come to the surface when examining or conceptualizing an urban situation. This lens can be added to other frameworks of analysis that remain productive. Moving forward, I hope to have some of the more promising speculative designs tested on the ground.

Dissertation Overview:

The Dissertation is divided into five major sections, (including this introduction), and one Coda. Each section opens with a brief introduction.

Part One: Introduction

Chapter One, the *Introduction,* establishes the research context, defines the key research questions, and outlines the main research tasks. It then provides an overview of how the dissertation is structured, and how each component of the research contributes to addressing the key research tasks.

PartTwo: Context - Overview of CAS principles and Urban Precedents

These three articles form part of the background research, in which I undertake a literature review and also look to precedents of urban design and planning that can be considered as examples of CAS.

Chapter Two in this section, *Research in Urbanism and Planning drawing from Complex Adaptive Systems theory: Divergent definitions, concepts, methodologies, and trends*, is the literature review that outlines the history of CAS theory, key contributions and various streams of urban thinking that draw from CAS.

Chapters Three and Four, *Situating Complexity in Contemporary Landscape Practice,* and *Tactical Urbanism as a means of testing relational processes in space: A Complex Systems Perspective*, outline different approaches to engaging CAS within the urban fabric. These chapters argue that two approaches to urban design – tactical interventions and landscape urbanism, do in fact work in ways that resonate with CAS, but that they do so in ways that are weakly theorized with regards to CAS.

Part Three: Hypothesis - The Urban Environment as Phase Space

This section presents the broad hypothesis that forms the core of the argument: that the characteristics of urban form are important in terms of how complex forces come to be anchored and situated in place: and that without the existence of particular kinds of urban form, certain productive urban processes may fail to become 'moored' even if other social, economic, and political factors are in place.

Chapter Five in this section, *Considering how morphological traits of urban fabric create affordances for Complex Adaptation and Emergence,* discusses how physical characteristics of the urban setting can have the capacity to either enhance or diminish its 'adaptive capacity'. Here I lean strongly on Martin Jones' (Jones, 2009) conceptualization of 'Phase Space', as the 'space of possibilities' wherein something can occur – and how this space can be expanded (or not). I attempt to outline a more explicitly *physical* component to this phase space, which Jones discusses in other terms (social, economic, etc.). The chapter draws strongly from concepts developed within Evolutionary Economic Geography but, again, adds a more explicit spatial dimension or *materiality* to the discussion. I argue that the relevance of urban form has been under-theorized within the larger geographic discourse, and

further argue that morphological processes can be discussed in a way that makes them analogous to CAS processes.

Chapter Six of this section, *From Form to Process: Re-conceptualizing Lynch in Light of Complexity Theory*, operationalizes this perspective, by providing a more explicit and concrete *framework* with which to discuss the varying processes that occur in complex systems, and how these might be framed in terms of morphology.

Chapter Seven of this section, *The Grand Bazaar in Istanbul: The Emergent Unfolding of a Complex Adaptive System*, is effectively a 'case study' that tests some the principles of Chapter Five, using the analytical methodology outlined in Chapter Six. It considers how the Grand Bazaar in Istanbul might be 'read' as an example of a complex adaptive system – where clusters of use emerge over the course of time in response to bottom-up emergent processes. Using the framework provided in Chapter Six, it outlines how physical characteristics of the Bazaar contribute to its capacity to exhibit emergent qualities. The article is based upon site analysis and interviews at the Bazaar, but also leans heavily upon concepts developed in EEG to frame the analysis of the dynamics at play from a CAS perspective (while expanding upon these with a more explicit material component).

Part Four: 'Augmented Morphology' - how information technologies allow us to re-read the city

The two articles in this section together discuss how the key features of materialized CAS processes might be further operationalized in a world where the physical 'stuff' of the urban fabric is augmented through digital capacities. Information is a core part of what makes a complex system unfold, and new informational capacities may take us beyond the standard morphological conditions that we are able to 'read', to enable augmented 'readings' that allow for new kinds of urban unfolding. This section, while speculative, is predicated upon the same principles outlined earlier– albeit with this augmented capacity for information transfer.

Chapter Eight of this section, *Conceptualizing urban infrastructures as 'smart', decomposable, and information-processing agents,* considers how the co-mingling of digital interfaces (apps and sensors) within 'smart' artefacts can augment evolutionary morphological processes.

Chapter Nine, *Sensing the City: Legibility in the context of mediated spatial terrains,* considers how the smartphone now acts as a sensory mediator of the urban environment, enabling new forms of information and evolutionary processes to unfold through a co-mingling of virtual and physical spaces.

Part Five: Conclusion

Chapter Ten of this section provides the *Conclusion* of the Ph.D. with closing remarks and a research summary. The section includes commentary on the relevance of the research outcomes as well as directions for future work.

The Coda, while pertaining to the core research of this dissertation, does so in a rather lateral and diffuse manner. The decision to include this article reflects my sense of its importance as part of my general research interests undertaken over the past number of years. The reader interested in engaging only with the central argument of the dissertation is, of course, encouraged to read the chapter, but its omission does not negatively bear upon the integrity of the overall thesis.

Chapter Eleven, *The Turkish Tea Garden: Exploring A Third Space with Cultural Resonances,* provides an analysis of an urban node in Turkish public space. It discusses the importance of a particular, physically situated and specific urban 'hub' where complex forces can intermingle.

§ 1.8 Notes on Reading the Dissertation:

A total of eight articles form the core body of this work. Each article forms a distinct component of research in and of itself, but together the manuscripts comprise a series of steps of the discussion that thicken into the overall subject of the Ph.D.

In reading the articles the reader is asked to bear in mind that there are certain redundancies between them, particularly when it comes to describing Complex Adaptive Systems. The articles have been submitted to different journals, the writing styles of which vary from the more technical to the more philosophical. Despite this stylistic variation, the submissions nonetheless thread together to form a cohesive whole. All were submitted as 'stand-alone' manuscripts, and therefore there is some repetition in content as one moves through the articles as compiled here. The journals where the articles appear often do not specialize in CAS perspectives, so in many cases the articles begin with a general overview of CAS, creating a good deal of overlap when the articles are read as a sequence.

Furthermore, this dissertation was prepared as a 'Ph.D. by publication'. As such, the links between publications were permitted to be somewhat 'looser' than in a typical thesis. The guidelines for a Ph.D. by publication provide more latitude for incorporating articles that are somewhat peripheral to the main discussion (while remaining, nonetheless, tied to the overall theme). Accordingly, Part Four of the dissertation, as well as the final Coda, are not as central to the discussion as Parts Two and Three.

Despite this, the articles do build upon one another in a sequence that moves from a broad overview (providing a literature review), to identifying case-study precedents for the research (the two articles that look at urban design strategies – tactical approaches and Landscape Urban approaches), to the specific – identifying the importance of urban morphological traits and then specifying the characteristics of these traits using a classification system that is already available and intuitive for design practitioners.

In order to orient the reader to the links between articles, each of the major parts of the manuscript begins with an introduction to the articles. These bridges are intended to provide a road-map to the logic of the PhD, but are not written as scholarly articles themselves. Accordingly, the reader should bear in mind that citations supporting the argument are not included in these introductory remarks, but are instead found in the chapter articles themselves.

PART 2   Context: Overview of CAS Principles and Urban Precedents

Introduction to Part 2

The three articles that follow set the context for this research. In them, I suggest that our way of thinking about CAS processes unfolding on the ground is currently under-theorized. I then go on to show examples of urban projects that nonetheless can be seen as informing a physically situated approach to CAS dynamics.

The first article serves to provide an overall literature review for the Ph.D. and is significant for two reasons. First, it provides a compilation of over-arching CAS principles that are relevant to the field as a whole. Second, it positions the specific morphological nature of this research within the broader scope of CAS research occurring within urbanism and planning. The next two articles provide some precedents for thinking about unfolding urban morphology. They also attune more closely to how the research within the dissertation is distinct from other urban studies informed by CAS.

Currently, there are no consistent 'general' principles of CAS that guide research. Accordingly, there is a high degree of confusion surrounding the nature of CAS research – is it primarily about power-laws, or bottom-up agents, or rules, or historic path dependence? This ambiguity results in various research streams involving CAS unfolding independently from one another, with little awareness of both overlaps, and conceptual differences. Accordingly, when groups of researchers come together to discuss ideas, they often find that while the source material (CAS) is the same, the way this source material has been developed and conceptualized is completely at odds.

That said, researchers across disciplines have generated lists of CAS principles, with many conceptual overlaps between lists. The first paper in this section examines these lists in an attempt to distill the most significant (and generally agreed upon) characteristics of complex systems. In choosing which lists to rely upon, I select only from those sources that have been highly cited. Of the eleven sources used, each has (at time of printing), been cited at least of 357 times (Gell-Mann, 1994) and up to a maximum of 4979 times (Holland, 1995). Distilling the cross-overs between these eleven sources provides a kind of conceptual road-map or 'cartography' of the field of CAS, with the hope that this can enrich cross-disciplinary dialogue. The distilled characteristics suggest CAS to be:

— Adaptive and evolutionary
— Described by scale free/nested mathematical hierarchies
— Organized through flows and interactions.
— Subject to non-linear and historical processes
— Characterized by self-organizing & emergent behaviours
— Comprised of a diversity of agents

The second part of this article then examines how urban research specifically locates itself within this cartography – highlighting the regions which are currently being deeply explored (such as the notion of organized flows) and noting regions where less research is underway. Here, I call attention to the work of what I call 'Incremental Urbanists': those interested in how urban morphological characteristics can be designed such that they are pre-disposed to changing over time in response to feedback. I posit

that, while this urban discourse is being somewhat examined, it still occupies a region that remains largely under-theorized.

While this chapter has not yet been published, the contents inform the overall structure of a website that is currently under construction. The website goes into further depth regarding each of the CAS definitions (with associated topics of inquiry) as well as the various research streams and how they draw from the six CAS attributes. A series of diagrams in this chapter (Figure 2.4; a - h) are screenshots from the website which, in the web version, are interactive. The interested reader is encouraged to visit the site (although it is currently operating under a temporary domain name and won't be completed until sometime in 2019 - see: cas.seanwittmeyer.com)

The second and third articles in this section take as their departure point the notion that there is a lack of situated and physical work drawing the world of CAS into the urbanism discourse. From the various research streams discussed, few locate their inquiry within the *physicality* of the urban and how physical qualities of urban space, in and of themselves, might leverage complex processes. This is discussed in greater depth in the third article of this section, but the takeaway from the review is that, while a number of urban research streams engage CAS, few explicitly examine how one might translate CAS dynamics into the urban design realm.

Accordingly, the second article highlights work underway within the domain of Landscape Urbanism (LU). LU theory does, in fact, share a clear ontological perspective with CAS – one that privileges processes, not objects, and embraces both uncertainty and the setting into motion of potentiality. In addition, LU projects are interested in how physical form might be curated such that it is 'pre-disposed' to change over time. Furthermore, unlike the majority of the CAS/urbanism research, LU practitioners share the interest I have with the conditions whereby urban morphological unfolding occurs 'on the ground'. As such, the work forms a relevant precedent which informs the Ph.D. research.

In order to bridge between the first and the second article, the key defining principles of CAS outlined in the first article are reintroduced in the second. These are shown to hold close parallels with principles highlighted from within the Landscape Urbanism theoretical discourse. Taking as reference a survey of seminal Landscape Urbanism texts, I highlight the stated principles of the discourse that most closely echo the CAS principles derived in the previous article. This yields the following list of parallels that highlight the resonances between CAS and LU principles:

— Adaptive and evolutionary | *Create catalyzing environments that adapt to unknown futures;*
— Described by scale-free/nested mathematical hierarchies | *Develop overlapping, interacting, organizational hierarchies;*
— Organized through flows and interactions | *Leverage infrastructure and flows;*
— Subject to non-linear and historical processes | *Allow for non-linear, open-ended, and contingent transformations over time;*
— Characterized by self-organizing & emergent behaviours | *Foster process-driven, emergent outcomes;*
— Comprised of a diversity of agents | *Activate bottom-up tactics and strategies to generate use.*

Using these parallels as an analytical framework, I then consider a series of hallmark LU projects through the lens of CAS. In selecting which projects to compare, I limit my choices to those that are highly referenced, and further limit these to ones I have personally visited (in the case of built works).

The analysis of the projects suggests that, while LU theory echoes a CAS ontological stance within its theoretical underpinnings and shares key terminology with CAS when describing the work, the seminal projects are, in practice, limited in how they put into play the principles we would

expect to see in a fully self-organizing physical environment. The adoption of CAS principles is often largely metaphoric in nature, based upon a 'loose' appropriation of terms rather than a more rigorous understanding of CAS dynamics. As such, the discourse could benefit from a more detailed understanding of how complex systems operate, in order to better graft this understanding into urban design situations.

That said, LU provides a highly relevant precedent for considering CAS processes that unfold on the ground in urban environments. The practitioners are clearly interested in creating physical environments that are 'primed' so as to be amenable to future change in response to unfolding conditions. LU accepts the relevance of taking an emergent approach to design and the kinds of methods that LU adopt 'on the ground' serve to illustrate how designers might begin to create physical environments that are primed to respond, over time, to evolutionary forces

The third article in this section turns to Tactical Urbanism (TU) as another example that can inform how CAS processes might be engaged within the urban context. While TU does not explicitly identify with CAS in any way (with some exceptions), it nonetheless provides a useful real-world example of how urban form can evolve incrementally on the ground as a response to site forces that are only loosely understood at the outset. The article begins by, once again, highlighting the difference between an 'on the ground' approach to CAS unfolding, as compared to much of the current urban discourses engaging CAS. I discuss three key discourses (again, drawing from the various research streams identified in the first article) that relate the urban to CAS – computational geography, communicative planning, and assemblage theory. I argue that each, while clearly considering the urban condition, relate more to discourses *regarding* the urban, rather than the physical substance and activation *of* the urban. The article moves on to examine an illustrative example, in this case a speculative competition entry that I helped design. This project was conceived using the lens of CAS to inform the design decision-making processes. The article discusses how elements of the project are conceived so as to behave in manners that follow the dynamics of complex adaptive systems.

The three articles provide a backdrop to the core of the thesis which follows. Together, they:

A   Delineate what is being discussed when referring to a 'complex adaptive system';
B   Identify the scope of the existing urban discourse surrounding CAS;
C   Highlight the area within this urban discourse that the Ph.D. wishes to engage more deeply (morphological unfolding);
D   Offer examples of precedents (both real and illustrative) that draw forth insights regarding how such morphological unfolding might manifest.

2 Research in Urbanism and Planning drawing from Complex Adaptive Systems theory: Divergent definitions, concepts, methodologies, and trends.

Abstract

Concepts derived from Complex Adaptive Systems (CAS) theory are exerting a growing influence on discussions surrounding urban geography and spatial planning (Boschma and Martin, 2010; Doak and Karadimitriou, 2007; Innes and Booher, 1999). However, 'CAS theory' while an overarching category, encompasses a wide breadth of concepts - quickly fragmenting into a plethora of ideas, each of which has its own relevant research agendas and methodologies. This paper aims to disambiguate these approaches and their relationships with CAS. To do so, the paper offers an overview of how various aspects of CAS have been appropriated within geography in general, and urban/spatial planning in particular. The paper begins with an overview of CAS principles and key concepts. It then defines key CAS features based upon a literature review of CAS definitions. Based on these features, the paper demonstrates how themes within spatial planning often centre around a particular set of CAS features while omitting others.

Key Words

Complex Adaptive Systems, Spatial Planning, Definitions, Epistemology, Urbanism

Note

The contents of this chapter are being developed into an interactive website, the draft of which can be found at: http://cas.seanwittmeyer.com/ (temporary domain name).

Introduction

When urban thinkers interested in CAS gather to discuss how complexity informs their research, they often find they are engaged in highly divergent areas of inquiry. These may pull conceptual threads from sources as diverse as biology, physics, mathematics, or philosophy, with concepts ranging from ideas concerning emergence, bottom-up versus top-down decision-making, network dynamics, relational flows, power-law distributions, and more. Though those applying CAS principles to urban topics do not necessarily limit themselves to considering only one aspect of CAS in their research, there does appear to be a tendency to centre upon particular traits and - depending upon this departure point - foreground certain issues while marginalizing others. Though common CAS

terminology across discourses might imply similar research agendas, the importance granted each term - and the concepts for which they stand - can vary significantly. This paper seeks to disambiguate approaches towards CAS thinking, providing an overview of how CAS traits have been appropriated within the spatial disciplines in disparate ways.

Part One introduces CAS, outlining its history and relevance for urban research while providing an overview of key principles and concepts. Part Two surveys various CAS definitions, proposing a synthesis of these that captures recurring CAS traits, and outlining how these traits form thematic clusters that situate modes of inquiry. Part Three considers how different streams of urban research engage these clusters themes, further mapping these relationships. I conclude with reflections on observations drawn from this cartography, discussing implications for further research.

§ 2.1 Part 1: Why Complexity?

Complex Adaptive Systems theory provides a means to understand, conceptualize, and analyse how bottom-up relationships can generate meaningful overarching structures. It provides tools with which to understand patterns that are generated by processes, where control of these processes is distributed amongst many actors or agents. It embraces an ontology predicated upon contingent and indeterminate processes and relationships, shifting our basic concepts of reality away from the concrete, object-oriented, and causal chains of thinking that, until recently, have dominated scientific discourse (Capra, 1997).

CAS are composed of interacting parts that adapt and change according to information and feedback mechanisms. These systems consist of an array of independent agents (nodes) interacting via connections (links) that allow them to process resources (in forms like that of energy, matter, or information), flowing amongst them (Holland, 1995, page 23). Interactions between agents act as signals that help generate emergent structures: ones that cannot be predicted a priori.

The study of CAS has emerged as a growing area of inquiry, spearheaded in part by research at the Santa Fe Institute (Holland, 1995; Kauffman, 1996; Waldrop, 1992). This work has spurred growing cross-disciplinary dialogue, as those from other disciplines harness CAS principles to address an array of systems - be they economic, political, or cultural. Urbanism is no exception, with CAS principles now informing spatial studies within a variety of discourses (see for example Batty, 2007; Healey, 2007; Portugali, Meyer, Stolk, & Tan, 2012; Urry, 2003). However, a long history of urban engagement with complexity pre-dates CAS as understood today. Jane Jacobs was amongst the first to identify cities as complex systems (1961). In her observations of urban settings, she adopts Warren Weaver's 1958 description of 'organized complexity' noting that cities, while complex, are neither 'accidental nor irrational'. That said, Jacob's conceptualization of complexity was primarily based upon research in the nascent fields of cybernetics and general systems theory.

Cybernetics[4] studied systems governed primarily by negative feedback, where systems 'correct' themselves in response to fluctuations so as to maintain an optimum operating regime. Cybernetics

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[4] A term coined by Norbert Wiener in 1948. Significant cybernetic researchers include Warren Weaver, Gregory Bateson, Gordon Pask, and Ross Ashby

concerned itself with how such systems *self-regulate*, with its insights therefore relevant for *any* system seeking to optimize performance in the absence of an external regulator (François, 1999; Wiener, 1948). Urban environments are one such system, comprised of parts together forming an environment that subsequently - in a recursive loop - regulates and alters the parts within. As such, a natural offshoot of cybernetic thought was conceptualizing ways in which healthy urban environments might be stabilized through cybernetic mechanisms (McLoughlin & Webster, 1970).

Systems theory, in turn, advanced the understanding of how *interactions,* as opposed to parts, might govern system dynamics. Here, the focus was primarily upon closed systems that might, in principle, be optimized. Ludwig von Bertalanffy recognized that systems science required a deeper understanding of systems that were also *open* to energetic exchanges between the system and its surrounding environment (von bertalanffy, 1968). In such cases system dynamics are *primarily* internal and bounded, but are nonetheless dissipative – capable of exchanging inputs, energy, matter, and information with their surroundings. Bertalanffy's interest in open systems was, however, primarily concerned with how they could maintain homeostasis *despite* this openness (Keller, 2008).

General systems theory aimed to determine if overarching meta-system principles might be derived, regardless of the specific system at play, or the nature of the parts. Urban Planners, influenced by this research began to take a 'systems view' of urban dynamics, whereby they analysed flows and stocks to determine optima or 'equilibrium' conditions (Forrester, 1969). Hence, by the early 1970s, a steady stream of research considered cities as complex entities (see McLoughlin and Webster, 1970).

Early references to complex city dynamics drew primarily from these general systems and cybernetic approaches. While there are clear relationships between these earlier antecedents and CAS, CAS differs in significant ways. Cybernetics, while concerned with interactions, focuses upon systems subject to *negative* feedback: ones self-regulating to maintain regimes of stable equilibrium (dampening disruptions or 'perturbations'). Systems theory focuses primarily upon *closed* systems where the role of external energy inputs is not strongly theorized, and internal relationships (the nature of which are assumed to be static) can be modelled (Manson, 2001).

CAS, by contrast, are open, non-linear, dissipative systems, with multiple, shifting equilibrium and the ability to generate new order. Here, system inputs like heat, energy, food, etc., can traverse dissipative boundaries and 'drive' the system towards order: seemingly in violation of the second law of thermodynamics (Heylighen, 1999; Prigogine, Stengers, 1984). As the intensity of such inputs increases, critical values are reached whereupon the system can move into different, but equally viable, potential states.

The 'choice' of these states is extremely sensitive, with small changes in initial conditions potentially leading to large shifts in the system's ultimate global behaviour. Further, as the amplitude of the relevant control parameter increases, the number of system states multiplies - eventually arriving at a 'chaotic' regime wherein all potential states are accessible. The total range of potential system states is equated with its 'degrees of freedom' or 'phase space' (Protevi, 2006).

Bifurcation diagrams and Reimann manifolds are used to help map the breadth and topology of this phase space (Casti, 1979), while also illustrating how systems can move between multiple potential states and shift suddenly at critical points. These threshold moments, dubbed 'catastrophes' by René Thom, 'bifurcations' by Mitchell Feigenbaum, and popularized as 'tipping points' by Malcolm Gladwell, coincide with moments when a system has the capacity to move into alternative regimes of newly available trajectories (such as in Benard experiments when water molecules form 'roll' patterns

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at critical temperatures that can either flow left to right or right to left), or when system components suddenly acquire new features (such as when water molecules turns to ice at a critical temperature).

In these last two examples, we note that the 'system' is made up of discrete elements - water molecules - that nonetheless behave as a group. CAS systems are always comprised of such parallel agents. To study their behaviours, we can conceptualize these as simple entities that come with 'pre-set' rules of behaviour, the activation of which is predicated upon interactions with surrounding agents. Investigations into such 'automata', informed the research of early computer scientists, including Von Neumann, Wolfram, Conway, and Epstein & Axtell. Simulations using Cellular Automata (CA) or Agent Based Model (ABM) sought to discover if stable patterns of global agent behaviours might emerge through interactions carried out over multiple iterations at the local level. These experiments successfully demonstrated how order does emerge through simple agent rules.

CAS are thus described as 'bottom-up', since higher levels of global order arise based upon simple interactions at the lower local level. Once these novel global features have manifested they stabilize, spurring a recursive loop that alters the environment within which the agents operate, and constrains subsequent system evolution. Maturana and Varela's notion of *autopoiesis* (see Luisi, 2003) as well as Haken's (1993) concept of enslavement, outline these dynamics, whereby order emerges stochastically but then stabilizes and self-maintains. Here, cybernetic thinking continues to leave its mark on CAS, as feedback is critical in preserving emergent properties.

While demonstrating emergent dynamics, CA/ABM are somewhat limited in that rules are generally static and established in advance. A richer exploration of agents in CAS examines the ways in which bottom-up agents might independently evolve 'rules' in response to feedback. Here, agents test various rules/schemas over the course of multiple iterations, assess their success through feedback, and retain useful patterns that increase fitness. These agents, each independently exploring suitable schema, actions, or rules, can be viewed as adopting general Darwinian processes to carry out 'search' algorithms (Holland, 2012). In order for this search to proceed in a viable manner, agents need to possess what Ross Ashby dubs 'requisite variety': enough heterogeneity to test multiple protocols and thereby increase the likelihood that fit rules or schemata will be discovered (Gell-Mann, 1994).

Discovering rules (or strategies) that increase global system fitness can be hastened by means of *information* (Shannon & Weaver, 1964). This can be framed as 'the difference that makes a difference' by creating distinctions between multiple potential system states (see Bateson, 2002, with reference to Shannon's information theory). In some CAS, agents themselves supply this information by generating signals or markers (stigmergy) that steer other agents' behaviours (Grassé, 1959; Theraulaz and Bonabeau, 1999). These signals direct agents towards regimes that are more operational: corresponding with 'peaks' within a fitness landscape (Kauffman and Johnsen, 1991; Pigliucci, 2008; Solé et al., 1999). Here, 'fitness' might range from finding a niche within an ecosystem, to gravitating towards behavioural regimes that minimize frictions in a fluid (such as occurs in the Benard rolls referenced earlier). Scientists have found that information is able to propagate most effectively in systems poised at certain states (described as 'the edge of chaos') wherein small system perturbations (disruptions) can trigger either small or large-scale cascading effects that propagate throughout the system (Kauffman, 1993; Langton, 1990; Strogatz, 2004). CAS have a tendency to move towards these states of 'self-organized criticality' where information transferring capacities reach their maximum (Bak, 1988; Solé et al., 1999).

Further efficiencies are achieved when agents aggregate and partition into nested hierarchies (Holland, 1995; Simon, 1962). The appearance of such hierarchies generally follows power-law distributions (noted by Zipf and Pareto), with those specific to urban phenomena having been studied

extensively by Bettencourt and West (2010). These topological regularities of CAS are intriguing, but their significance is not limited to their beauty as patterns per se but rather to how these patterns serve to channel information flows through optimizing distribution systems (though the fractals described by Mandelbrot are visually striking).[5]

CAS are intriguing to urban planners and spatial practitioners for numerous reasons. First, they demonstrate an 'alive' quality - being open to energy, learning and adaptation, and giving rise to novel entities. This is relevant to those interested in creating convivial urban settings. Second, CAS 'learn' over time, meaning that more 'fit' urban forms could evolve by channelling CAS dynamics. Third, CAS respond adaptably to external 'shocks' or system perturbations. This suggests a capacity for urban environments to be resilient in the face of change. Fourth, CAS are steered by bottom-up agents, suggesting alternatives to the failures of top-down master planning. Finally, CAS speak about relations rather than objects: a perspective strongly resonating with contemporary geography's interest in relational dynamics (Urry, 2003).

§ 2.2   Part 2: Defining CAS:

While various researchers have sought to define 'principle' components of Complex Adaptive Systems, these principles vary with no 'authoritative' definition in place. Surveying CAS, Philosopher Paul Cilliers remarks, *'the concept remains elusive at both the qualitative and quantitative levels'* (1998, page 2). Francis Heylighen echoes this sentiment, stating:

Qualitative descriptions can be short and vague, such as 'complexity is situated in between order and disorder'. More commonly, authors trying to characterize complex systems just provide extensive lists or tables of properties that complex systems have and that distinguish them from simple systems. These include items such as: many components or agents, local interactions, non-linear dynamics, emergent properties, self-organization, multiple feedback loops, multiple levels, adapting to its environment, etc. The problem here of course is that the different lists partly overlap, partly differ, and that there is no agreement on what should be included. (2007, page 4)

These disagreements result in considerable ambiguities in how concepts are discussed. Different discourses engaging CAS often employ descriptors that, while intending to describe the same features, are generally not agreed upon. Hence, terms including *'manifold'*, *'phase space'*, *'space of possibility'*, and *'the virtual'* all essentially refer to the same thing. Crucially, even principle terms such as emergence and self-organization remain subject to debate.[6] The word 'complexity' itself is often conflated with the word 'complicated'.[7] Meanwhile, some researchers qualify CAS according

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[5]   The topological study of fractals, such as those found in growth patterns in plants can be seen as enabling nutrients to flow along minimal pathways while covering a maximum area.

[6]   For an overview of types of emergence see Bonabeau (1995); for a critique of the conceptual novelty of emergence see Epstein (1999); for considering Emergence within Philosophy of Science see Bedau and Humphreys (2008); For definitions of self-organization see Gershenson and Heylighen, (2003)

[7]   Complicated systems are not Complex if they are quantifiably reducible (Reitsma, 2002).

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to governing mechanisms, distinguishing between algorithmic, deterministic, and aggregate complexity (Manson and Sullivan, 2006). Others use terminology in metaphoric ways – where any choice becomes a '*bifurcation*' point, regardless of whether or not this is a threshold associated with a relevant control parameter. The ever-increasing array of terms and concepts makes it increasingly difficult to gain insights across discourses.

The phrase 'Complex Adaptive System' itself has an ambiguous history. Sociologist Walter Buckley (1967), informed by systems and cybernetic approaches, introduced the phrase to discuss aspects of the personality. However, the use of the term 'adaptive' is deceptive, as it was not intended to describe the nature of the system itself, but rather act as a qualifier on its human element - a cognitive subject possessing 'adaptive capacity'. By contrast, as early as 1962 Herbert Simon described systems one would now call CAS, but while he speaks both of 'complex systems' and their 'adaptiveness' he does not employ the phrase nor offer a definition of what such systems would entail (Simon, 1962).

CAS as understood today can be traced back to the mid 1980s at the newly formed Santa Fe Institute. In the summer of 1986, the institute announced a workshop on 'Complex Adaptive Systems' described as, '*systems comprising large numbers of coupled elements the properties of which are modifiable as a result of environmental interactions*' (Cowan and Feldman, 1986). Both Holland and Gell-Mann adopt this usage by the mid 1980s, but no mention of its meaning seems to be circulated until the early 1990s - at which point various definitions of CAS appear outlining its 'principles', 'attributes' or 'defining features'.

Of the definitions circulated since that time, I have chosen eleven highly cited references to compare, including definitions offered by Anderson, (2008); Arthur et al., (1997); Cilliers, (1998); Dopfer et al., (2004); Gell-Mann, (1994); Heylighen, (1999); Holland, (1995); Levin, (1998); Martin and Sunley, (2007); Mitleton-Kelly, (2003); and Taylor, (2002). While specific terminology amongst these differ (and there is a lack of consistency regarding which CAS aspects are highlighted), there nonetheless remains a great deal of overlap between the respective traits when considered as a group **(Figure 2.1)**. The general defining traits surmised from this literature review suggest CAS to be:

— *adaptive, evolutionary, and rule-based;*
— *comprised of a variety of agents;*
— *described by scale free/nested mathematical hierarchies;*
— *characterized by self-organizing and emergent global properties;*
— *organized by flows and interactions; and*
— *subject to non-linear and historical processes.*
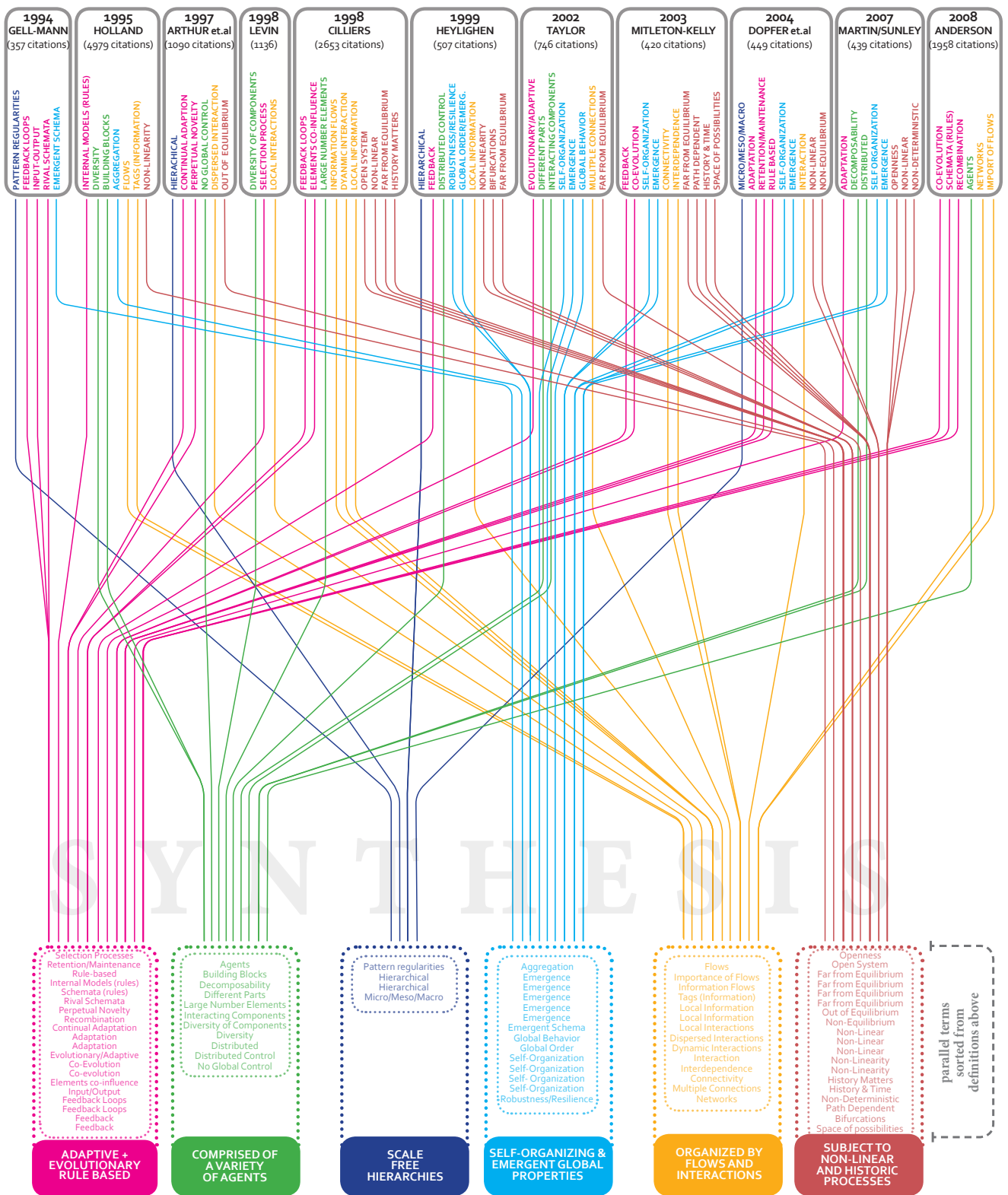
FIGURE 2.1 CAS Definitions

I have identified that the various defining traits can be assigned into three distinct cluster areas **(Figure 2.2).**
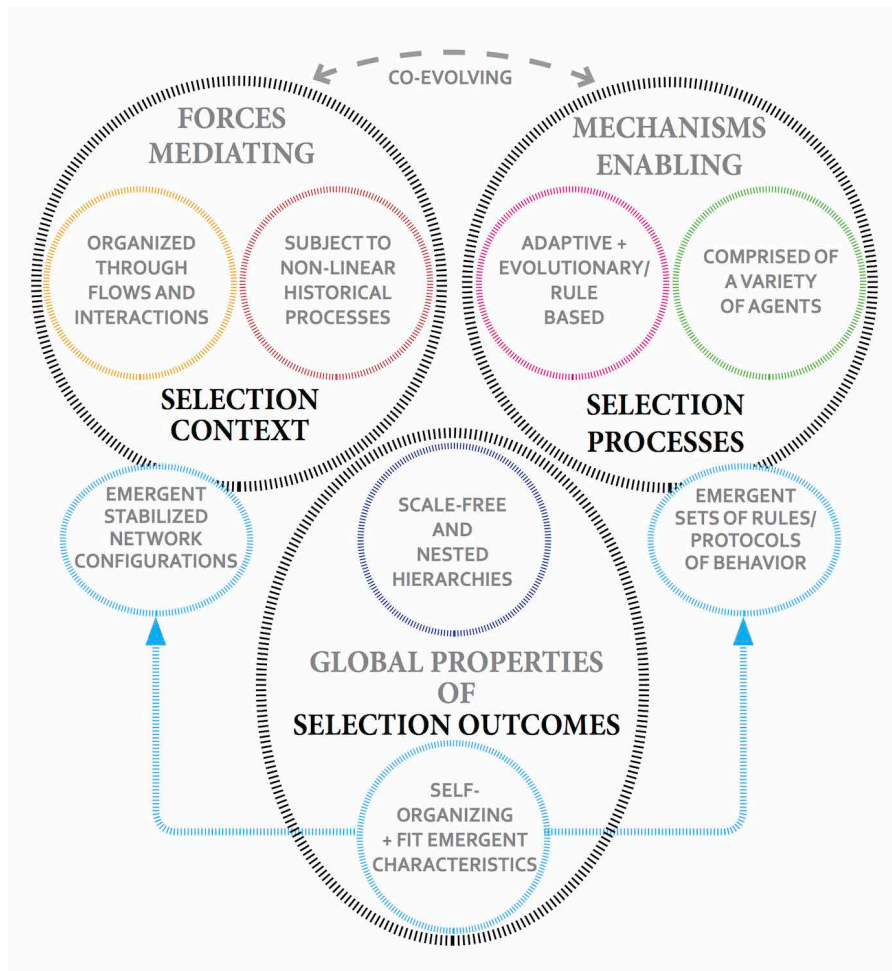
FIGURE 2.2 Three Distinct Cluster areas (mechanism, forces, properties)

1 **Mechanisms enabling selection processes** (including):
   – *adaptive and evolutionary/rule based*
   – *comprised of a variety of agents (= Emergence of fit agent behaviours/rules or schema)*

2 **Forces mediating selection context** (including):
   – *organized through flows/interactions*
   – *subject to non-linear/historic processes*

3 **Properties of selection outcomes** (including):
   – *scale free/nested hierarchies*
   – *self-organizing and emergent global properties*

The **first cluster** focuses upon the processes whereby agents adjust and respond to their environment, including the mechanisms that enable selection and evolutionary processes to occur. Here, the trial and error nature of CAS, with its capacity to find 'fit' operational strategies centres the research. Those interested in this aspect of CAS draw from biology, (Darwinian processes and fitness), and computational theory (simple rules yielding rich global dynamics). We can also speak here about the 'emergence' of individual actor protocols, schema or rules – even though these are not global properties characterizing the system as a whole (discussed below).

The **second cluster** focuses on the role of the context wherein evolutionary processes occur. This pertains to the nature of forces mediating the selection context wherein adaptation occurs. For CAS to evolve and discover fit configurations, this context needs to incorporate some form of energy, driving different potential trajectories (Morowitz & Smith, 2006). The way in which these flows are channelled is subject to historical circumstances, contingency, degrees of freedom, and phase space.

The **third cluster** focuses upon the emergent manifestations or *results* of CAS processes. While 'Emergence' refers to the unexpected manifestation of unique phenomena occurring in the absence of top-down control, it can refer both to the novel global phenomena themselves (ant trails, Benard rolls or traffic jams); or to the mathematical regularities associated with these phenomena (power law distributions).[8] In each case, interest is not so much on considering the specific evolutionary processes leading to such regularities, but rather on identifying the kinds of phenomena exhibiting such properties.

§ 2.3 Part 3: Drawing from CAS phenomena

When researchers appropriate CAS ideas and terminology, they naturally tend to draw from those concepts that resonate with their pre-established research biases. Depending on these, different concepts, mechanisms, and authors are highlighted. **Figure 2.3** illustrates how CAS has been appropriated within urban research, outlining key streams, pertinent researchers, as well as complementary sources that co-influence the various perspectives. Selecting which research to include does not involve a clear, replicable methodology. In some cases, I include authors who are highly cited in their field, but draw from CAS only peripherally (Healey for example). Others boast fewer citations but are unique in having explicitly clarified the overlaps between their area of inquiry and CAS (Prominski, for example). Further, while all areas hold connections to CAS, some are not yet explicitly articulated. Thus, strong conceptual overlaps exist between Tactical Urbanism (learning by doing/adaptation); Resilient Urbanism (ability to absorb system perturbations); and Urban Informalities (bottom-up and evolutionary) to CAS. These links, while implicit, remain largely under-theorized. At the same time, not all urban theory pertaining to CAS can be neatly arranged within the categories offered – while I have aimed to include as many clear topics as possible, some engagements defy easy classification even though they remain relevant (see, for example, Comunian, 2010).

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8   CAS does not distinguish between emergence manifesting as patterns formed by agents – such as ant trails - versus patterns formed by the environmental context within which the agent is situated (such as termite mounds, a 'stigmergic' medium (Grassé, 1959)).

MECHANISMS ENABLING SELECTION PROCESSES

GLOBAL PROPERTIES OF SELECTION OUTCOMES

FORCES MEDIATING SELECTION CONTEXT

KEY CONCEPTS + THINKERS
Darwin, Kauffman, Von Forster, Wiener, Gell-mann, Axelrod, Langton

- Artificial Life
- Schemata
- Feedback
- Trial/Variation
- game theory
- Adjacent Possible
- Cybernetics

ADAPTIVE & EVOLUTIONARY RULE BASED

KEY CONCEPTS + THINKERS
Simon, Holland, Wolfram, Conway, Von Neumann, Ashby, Epstein/Axtell

- Requisite Variety
- Automota
- Nested
- Building Blocks
- Bottom-up
- Agent-based

COMPRISED OF A VARIETY OF AGENTS

KEY CONCEPTS + THINKERS
Mandelbrot, Pareto/Zipf, Barabasi, Bak, M.Newman, Kauffman, Bettencourt/West

- Fractals
- Power Laws
- Self-Organized Criticality

SCALE FREE HIERARCHIES

KEY CONCEPTS + THINKERS
Maturana/Varela, Haken, Kauffman, S. Wright

- Auto-poesis
- Fitness Peaks/Landscape
- 'Fit' behavior protocols
- Enslaved States
- Emergence of Mathematical Regularities

SELF-ORGANIZING & EMERGENT GLOBAL PROPERTIES

KEY CONCEPTS + THINKERS
Strogatz, Shannon, Weaver, Bateson, Barabasi, Grasse, Bonabeau, V. Bertalanffy

- Preferential Attachment
- Systems Thinking
- Information/Negentropy
- Network Topology
- signals/stigmergy

ORGANIZED BY FLOWS & INTERACTIONS

KEY CONCEPTS + THINKERS
Poincare, Thom, Rieman, Prigogine, Stengers, Feigenbaum, Lorenz

- Time's Arrow/
- Bifurcations/Catastrophies
- Multiple Trajectories/Equilibria
- Sensitivity to initial conditions
- Open/Dissipative
- Degrees of Freedom
- Manifold
- Phase Space

SUBJECT TO NON-LINEAR & HISTORIC PROCESSES

EMERGENCE 'fit' behavior rules//protocols

URBANISM + PLANNING ASSOCIATIONS/APPROPRIATIONS:

TACTICAL URBANISM
BOTTOM-UP, TESTING/PROTOTYPING, ITERATIVE
Lydon, Garcia, Stealth, S v.d. Beek

INCREMENTAL URBANISM (morphology based)
RULE-BASED, ITERATIONS, EVOLVING, FEEDBACK LOOPS, BOTTOM-UP ELEMENTS, NO CENTRAL CONTROL, UNIT BASED, TENDS TOWARD FRACTAL/ SELF-SIMILARITY, 'FIT' BUILDING BLOCKS
Habraken, Salingaros, Porta, Schneider/Till, Marshall, Portugali, Siksna
(Cannigia, Conzen, Muratori, Alexander, Jacobs)

URBAN INFORMALITIES
FEEDBACK LOOPS, RULE BASED, ITERATIONS, ELEMENTS, MODULAR, LARGE NUMBER, BOTTOM-UP, FRACTAL PATTERNS, FIT BUILDING BLOCKS/RULES, COHESIVE URBAN PATTERNS
Ben Hamouche, Hakim, Araveno, Dovey, Mcfarlane
(Rudofsky)

URBAN COMPUTATIONAL MODELING
SIMPLE RULES, FEEDBACK LOOPS, ITERATIONS, VARIABLES, BUILDING BLOCKS, MATHEMATICA, FIT SCHEMA, ATTRACTOR STATES, DYNAMIC INTERACTIONS, MULTIPLE SCENARIOS
Batty, Benenson, Torrens, Pumain, Allen, Tom Evans
(Schelling, Ulam)

EVOLUTIONARY ECONOMIC GEOGRAPHY
FEEDBACK LOOPS, RULE-BASED, LARGE NUMBER OF AGENTS, FIRM RULES/PROTOCOLS, PREFERENTIAL ATTACHMENT, FLOW OF ENERGY, LOCAL INTERACTIONS, PATH DEPENDENT, NON-LINEAR
Boschma, Martin, Sunley, Sheppard, Franken, Yeung
(Hayek)

LANDSCAPE URBANISM
FEEDBACK LOOPS, FIT CONFIGURATIONS, COMBINING TOWN, UNFOLDS VIA INTERACTION, OPEN SCAFFOLDS, INDETERMINANT SPACE, UNFOLDING OVER TIME, AFFORDANCES
Koolhaas, Waldheim, Corner, Stan Allen, Rietveld/Rietveld, Belanger, Prominski
(McHarg)

COMMUNICATIVE PLANNING
BOTTOM-UP, DIVERSITY OF AGENTS, CONSENSUS, DYNAMIC INTERACTION, INTERDEPENDENCE, MULTIPLE EQUILIBRIA, BIFURCATIONS
Healey, Innes/Booher
(Habermas)

RESILIENT URBANISM
REDUNDANCY, NESTED HIERARCHIES, MULTIPLE EQUILIBRIA, SAFE TO FAIL
Brand, Ahern, Pickett, Fernandez

ASSEMBLAGE GEOGRAPHY
AGENCEMENT, STABILIZED ASSEMBLAGES, RHIZOMES, HISTORY, CONTINGENCY, MANIFOLD, "THE VIRTUAL"
Ignacio Farias, Jean Hillier, Jason Dittmer, Kim Dovey, McFarlane/Anderson, John Protevi
(Deleuze/Guattari, Delanda)

RELATIONAL GEOGRAPHY
PATTERNS OF INTERACTION, NETWORK TOPOLOGY, FLUIDITY/MOBILITY, RELATIONS BETWEEN, OPEN DISSIPATIVE
Ole Jensen, Amin/Thrift, John Urry, Massey
(Latour, Castells)

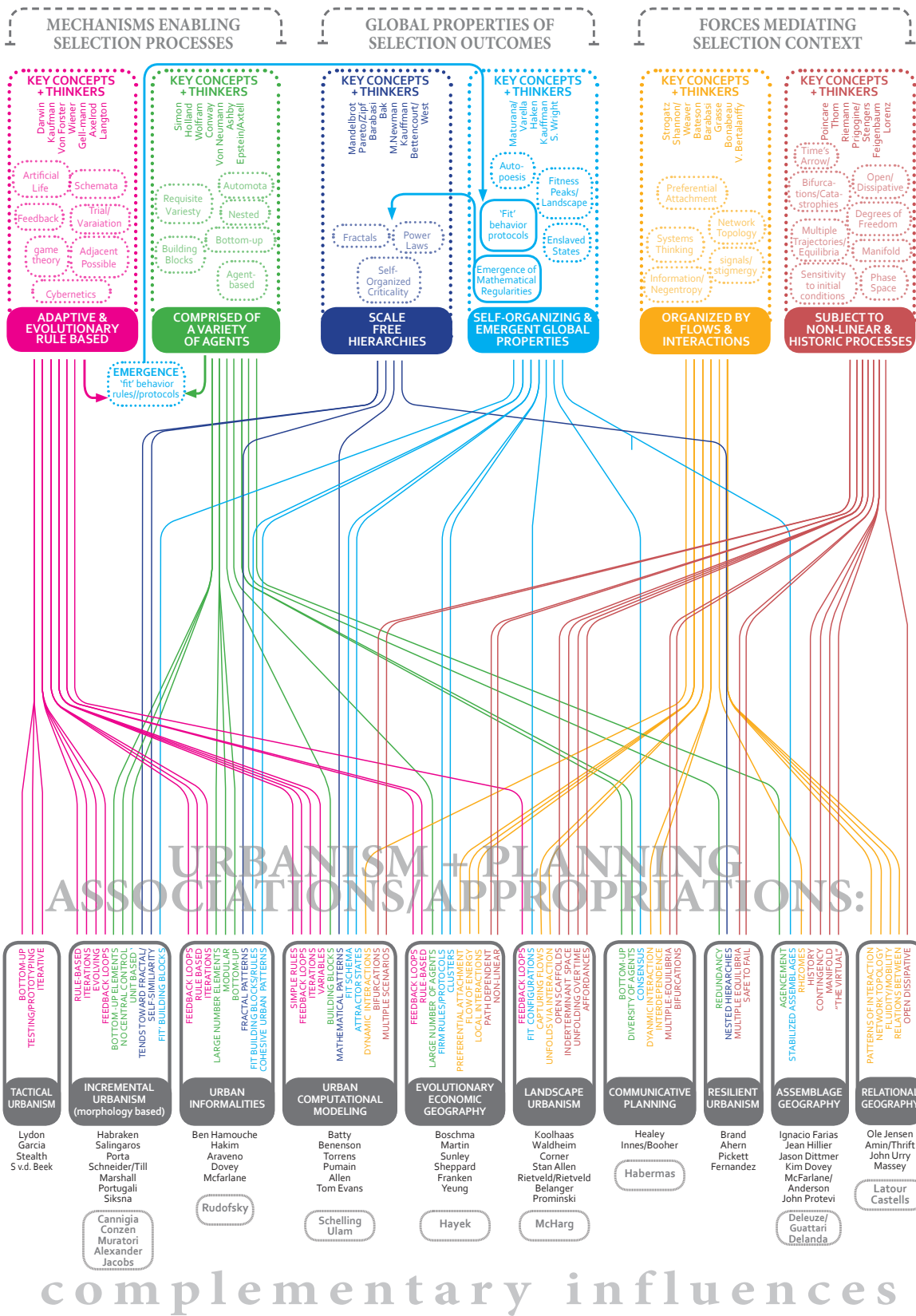**complementary influences**

FIGURE 2.3 Streams of Urban Thinking as related to CAS principles:

Finally, no map is ever precise. Conceptual overlaps persist between concepts, authors, and categories. I will be the first to acknowledge that the act of mapping boundaries in a field concerned with relations may be regarded as highly suspect. I hope to convey that the boundaries I trace are best viewed as 'open and dissipative'. I make no claims that this rough cartography is so much definitive, as that it provides an intuitive grasp of how one might begin to navigate amongst different perspectives, guided by various landmarks even if the overall territory remains somewhat vague.

With this proviso in place, we can begin to observe how specific streams of urban inquiry draw from CAS in distinct ways. Each (with different ends in mind), highlights different components, focuses on distinct dynamics, and engages specific terminology to speak of parallel concepts. A series of comparative diagrams,[9] shown in **[Figure 2.4],** are derived from Figure 2.3 and illustrate these differences. By analyzing how the distribution of the lines in Figure 2.3 (and in some cases the density of lines) flow from the CAS concepts into the various discourse boxes, we begin to structure an understanding of how CAS concepts are highlighted differentially within each urban research stream. Again, this is not to suggest that where certain concepts are highlighted others are completely overlooked; instead, what is offered here is a way to see how the various attributes of CAS are granted focus differentially according to the area of inquiry.

Table 2.1 (at the end of this section), provides an overall summary of each branch of research's relation to CAS. Areas that remain peripheral are assigned to 'the margins' (though some engagement may occur). Areas forming the major thrust of the research are highlighted, and areas that are somewhat theorized but not central to the discourse are noted. These distinctions are intended to points to areas of overlap, as well as note clear disjunctures. While an in-depth review of each stream lies outside the scope of this paper (and can be pursued by reading the referenced sources), the comparative table helps highlight how significant differences exist in the ways each urban discourse positions itself in relation to CAS.

In what follows, I briefly discuss a selection of these urban discourses as they pertain to the three clusters areas.
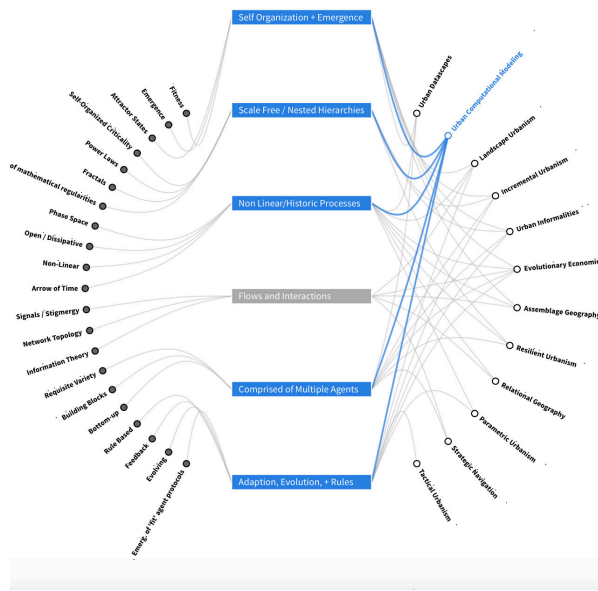
3.1 Mechanisms Enabling Selection Processes

Urban Computational Modellers, as a group, are highly engaged in this particular cluster. They develop Cellular Automata or Agent Based Models (Batty, 2007a; O'Sullivan and Torrens, 2001; Wolfram, 1984) placing an emphasis on the 'rule-based' nature of CAS. CA/ABM researchers attempt to infer the rules at play within a particular realm, calibrating these such that model behaviours reflect real-world phenomena. Emphasis is placed upon how simple agent-based rules yield emergent outcomes, and how rules might be varied to make these outcomes more desirable.

Evolutionary Economic Geographers (EEG) consider how firms – conceptualized as agents in economic systems, 'learn' and 'evolve' by processing resources and information such that geographic clusters emerge. Here, the firm is the basic unit of analysis, and General Darwinian processes are invoked to describe how firms adapt to shifting economic contexts. EEG unpacks CAS dynamics unfolding 'on the ground' observing how behavioural 'rules' of firms compete for fitness (Boschma and Martin, 2010).

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[9]   The diagrams shown are screenshots from the author's website dealing with Complex Systems and Urbanism (currently under construction). More detail can be found by accessing cas.seanwittmeyer.com (temporary domain name).

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a   *Computational Geography's emphasis vis a vis CAS*
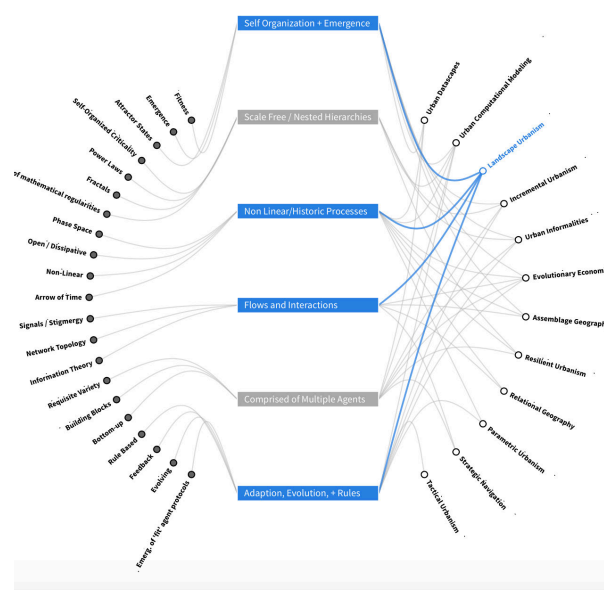
b   *Landscape Urbanism's emphasis vis a vis CAS*
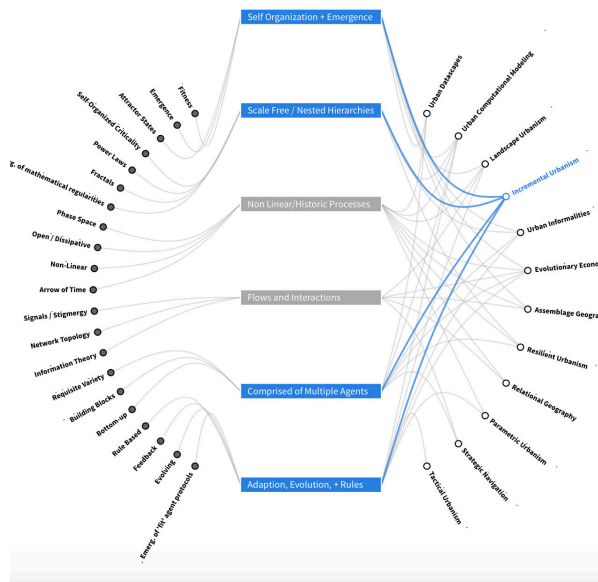
c   *Incremental Urbanism's emphasis vis a vis CAS*
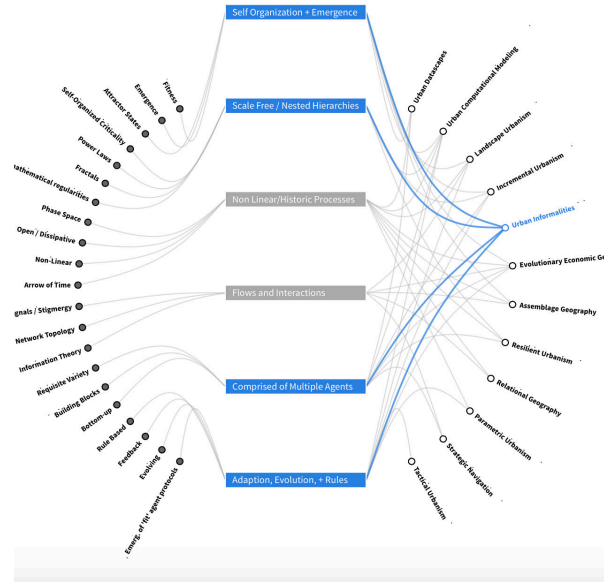
d   *Urban Informality's emphasis vis a vis CAS*

FIGURE 2.4 Summary of various urban research stream's focus vis a vis CAS, indicating which attributes dominate each reasearch agenda
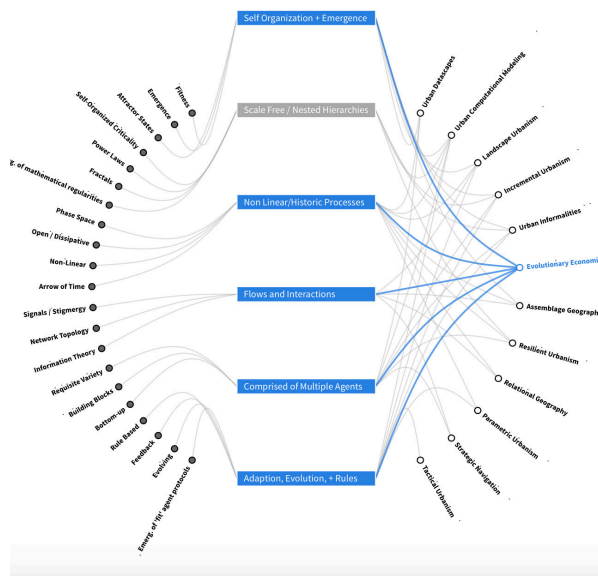
e   Evolutionary Economic Geography's emphasis vis a vis CAS
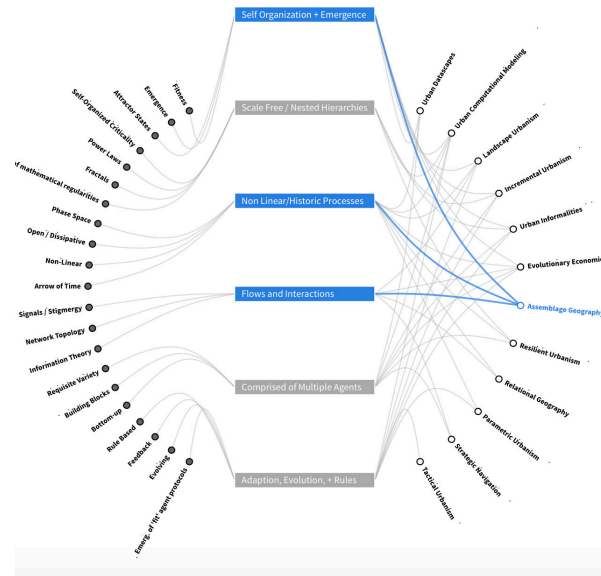
f   Assemblage Geography's emphasis vis a vis CAS
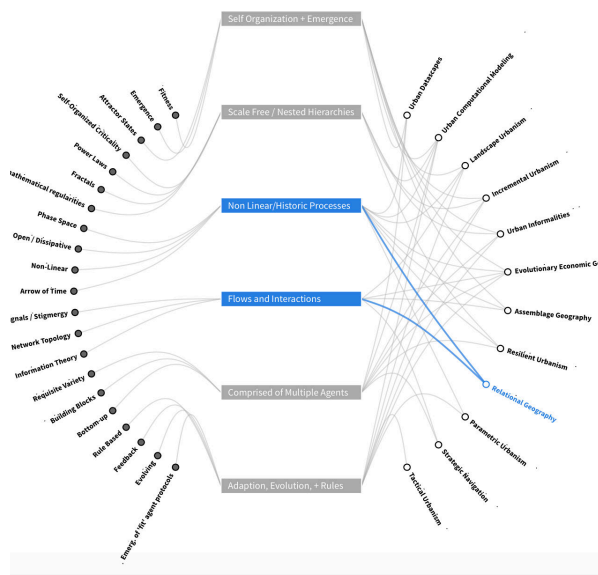
g   Relational Geography's emphasis vis a vis CAS
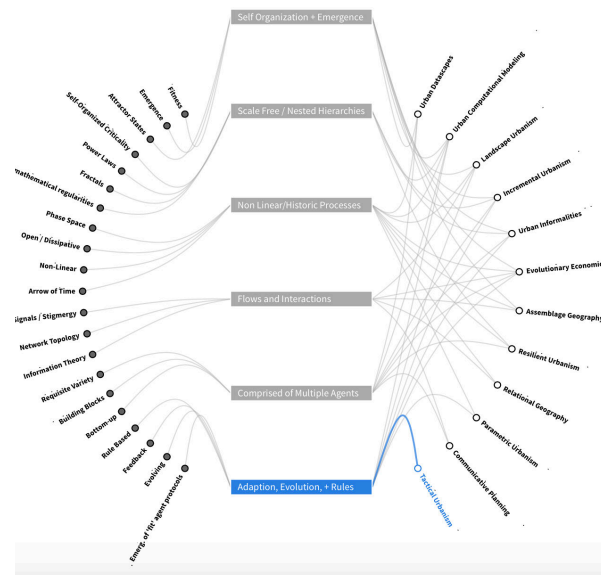
h   Tactical Urbanism's emphasis vis a vis CAS

For Communicative Planners, CAS informs a potent political agenda: engaging human-based diversity to empower a range of stakeholders within planning processes (Healey, 2007; Innes and Booher, 1999). CAS is used as a metaphor to inform the efficacy of bottom-up communicative processes. Communicative Planners recognize that cities are complex, but rather than trying to control this uncertainty, they seek to embrace it, working to strategically navigate uncertain scenarios, while understanding that managing discourse involves mediating between an uneven terrain of stakeholders (Balducci et al., 2011; Portugali and Alfasi, 2008). Here, agents are individuals, and agent-based behaviour is conceptualized in terms of how it informs the democratizing aspects of

urbanism. As David Byrne notes *'complexity is emancipating'*. He continues, *'this is very far from trivial and may be the most important single thing complexity can give to us'*(2003, page 175).[10]

Those I categorize as 'Incremental Urbanists', are interested in how morphological features of urban components might be predisposed to channel evolutionary potential: with an inherent plasticity that can respond to complex forces. Within this context, the 'bottom-up' agent is neither an individual (as in Communicative Planning) nor a computer cell (as in CA/ABM), but rather a physical built unit (home, building, block) that changes over time. Rather than directing change through planning, this stream concerns itself with how the morphological features of the built environment might physically be designed so as to be more responsive to unfolding social, economic, and political realities (Habraken, 1987; Hakim, 2007; Jankovic, 2012; Schneider and Till, 2006; Till and Schneider, 2006). The research work to understand the nature of *'more adaptable urban tissues, capable of adjusting to changing demographics, economics and cultures over time'* (Porta et al., 2014, page 3399). It focuses upon bottom-up day-to-day socio-spatial evolution occurring in situ, and therefore resonates with both urban informalities and tactical urbanism. While highly relevant, explicit links to CAS theory within this stream are to a large extent under-theorized (for reflections see Marshall (2008).

3.2 Forces Mediating the Selection Context

Relational Geographers, draw attention to the primacy of relations and flows in constituting meaning and space (Massey, 1999). Here, CAS is appropriated to inform an ontology dealing with multiple, contingent, shifting, and flexible relations. The focus is, therefore, less about the specific processes of agent evolution, and more about flows (informational, material, energetic, technological), that drive evolution (Jensen, 2009; Urry, 2005). It is the properties of these flows – their nature, thickness, extension, etc. – that become the departure point for analysis, with research unpacking how flows amongst agents and territories are reinforced, moored, or grounded (Hannam et al., 2006; Urry, 2004). Here, shifting flows that are both local and global, thicker and thinner, and often overlapping are examined *'within a complex system [that] supports the postmodern view of a multiplicity of localized, yet networked, social and political discourses.'* (Manson, 2001, page 411).

Assemblage Geographers, seize upon concepts of path dependency and bifurcation points – moments when chance events determine the trajectory of systems sensitive to historical unfolding. Here, in order to properly conceptualize actualized geographical space, it is necessary to see this as being the manifestation of only one particular trajectory - situated within a much broader virtual phase space - of potentiality (Jones, 2009). This introduction of history situates urban systems as contingent, with actual behaviours representing only one potential trajectory of much 'phase space' potentiality. Assemblage thinking frames phase space through the notion of 'the virtual' (DeLanda, 2005), the 'plane of immanence' from which capacities are activated in response to the situation at hand.

Landscape Urbanists (LU) are also interested in this 'space of possibility', but understand this as physical spaces 'seeded with potential' or 'providing affordances' for unfolding actions. Rather than designing for a 'fixed' future, LU practitioners create 'scaffolds' or 'stages' in which multiple possible futures might unfold (discussed in Chapter 3). The nature of which future ultimately actualizes is predicated on flows and stochastic processes outside of the designer's control. Thus, providing enabling spaces - which can manifest in different states of equilibrium - becomes the design objective.

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10   While this perspective focuses on empowerment, it has recently been the subject of critique as 'self-organization' is seen as a way governments might shift responsibility onto local actors in an effort to slash budgets (see for example Uitermark, 2015).

Computational Geographers are also interested in features of phase space but approach this differently. Rather than considering ways in which phase space is activated in situ, they attempt to understand which states are most likely to unfold in real-world scenarios by running multiple iterations of simulation models and noting tendencies.

3.3 Global Properties of Selection Outcomes

Computational Geographers tend to highlight the mathematical regularities that manifest both in real cities and in urban simulations (Batty, 2007a). Evolutionary Economic Geographers (EEG), are also intrigued by the general phenomena of emergent urban patterns, noted as 'clusters' of firms. While the first group tends to highlight the mathematical regularities, EEG is more interested in the functional aspects of how such emergent agglomerations drive efficiencies and innovation through reinforcing feedback mechanisms (Boschma and Frenken, 2005; Martin, 2001; Yeung, 2005). [11]

Communicative Planners consider how strategic planning can lead to an emergent consensual agreement between various stakeholders and thus a 'fit' planning strategy. Here, the metaphor of 'emergence' is somewhat stretched. DeWolf and Holvoet (2004) note that self-organization (as advocated by communicative planners), occurs without technically leading to emergence. That is, there is a difference between an emergent feature in CAS (arising from autonomous agent actions) and a resultant feature that is in fact deliberated upon by a group of autonomous agents within a communicative process (see also Crutchfield (1994)).

Assemblage theorists consider emergence in a more philosophical guise. Drawing from the works of Deleuze, Guattari, and Delanda concrete entities are situated as emergent, indeterminate and historically contingent stabilized assemblages (Jacobs, 2011; Sheppard, 2008). Assemblages are brought into existence through distributed agency (Anderson and Mcfarlane, 2011) amongst both human and non-human actants (Protevi, 2006). 'Agency' is substituted with the notion of *'agencement'* - *'arrangements endowed with the capacity of acting in different ways depending on their configuration'* (Jacobs, 2011, page 417). Dovey (2012), proposes adopting the phrase *'complex adaptive assemblage'* to define assemblages. He highlights their similarity to *'emergent structures'*, wholes that are, *'formed from the interconnectivity and flows between constituent parts – a socio-spatial cluster of interconnections between parts wherein the identities and functions of parts and wholes emerge from the flows among them'* (2012, page 353). Assemblages are thus configurations of inter-meshed forces - human/non-human, local/non-local, material, technical, social, etc., - stabilized at particular moments. Once in place, these take on agency in structuring further events. Agents in a particular assemblage hold multiple capacities (DeLanda, 2005), but how these capacities manifest is contingent: predicated upon the nature of forces, flows, or interactions at play in a given situation. While assemblage theory has been critiqued for its vagueness and jargon (Storper and Scott, 2016), it strongly resonates with the CAS ontology outlined above.

Although not included in this cartography, many social scientists are also interested in the philosophical implications of emergent phenomena (for a general introduction see Bonabeau, 1995; Wolf and Holvoet, 2004). Emergent phenomena pose ontological questions regarding where agency is located, since phenomena arising from agent behaviours subsequently acts upon and constrains these behaviours. This is framed as *'supervenience'* (de Haan, 2006), which characterizes how *'an*

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11   A similar discourse appears in management literature.

emergent property might be one that supervenes on, without necessarily being definable in terms of (or reducible to) a physical base' (Baas and Emmeche, 1997). Here, 'the recursion lies in the effect that their adaptive behaviour leads to alteration of the phenomena they adapted to' (de Haan, 2006, page 298). Further questions have been raised regarding the role of the observer in perceiving 'emergence', and how this observer is then implicated in CAS unfolding (see Bedau and Humphreys, 2008). This self-reflective aspect of human entities, themselves part of CAS, is the subject of recent research in planning and cognition (Portugali and Stolk, 2016).

CAS CLUSTERS					
Mechanisms Enabling Selection Processes		Forces Mediatiing Selection Context		Properties of Selection Outcomes	
Adaptive & Evolutionary /Rule Based	Comprised of a variety of Agents	Organized via flows & Interactions	Subject to non-linear & historic processes	Scale Free/ Nested Hierarchies	Novel & emergent global properties (what emerges)
Communicative Planning: MARGINS	THEORIZED - bottom-up; - diversity of agents	FOCUS - dynamic interactions; - interdependence	THEORIZED - multiple equilibria; - bifucations	MARGINS	Emergence of: - consensual agreement
Incremental Urbanism FOCUS - rule-based; - iterations; - evolving; - feedback loops	FOCUS - bottom-up elements; - no central control; - unit-based	MARGINS	MARGINS	THEORIZED - rule based; - iterations; - evolving; - feedback loops	Emergence of: - fit building components; - cohesive urban patterns
Assemblage Geography MARGINS	THEORIZED - agencement	THEORIZED - rhizomes	FOCUS - history; - contingency; - manifold; - phase space; - the virtual	MARGINS	Emergence of: - stabilized assemblages
Relational Geography MARGINS	MARGINS	FOCUS - patterns of interaction; - network topology; - fluidity/mobility; - relations between	THEORIZED - open /dissipative	MARGINS	MARGINS
Urban Informalities FOCUS - rule-based; - time/iterations - feedback loops	FOCUS - large number of elements; - modular; - building blocks	MARGINS	MARGINS	THEORIZED - fractal patterns	Emergence of: - fit building blocks/ rules; - fit global configurations
Evolutionary Economic Geography FOCUS - rule-based; - feedback loops	INTEGRATED - large number of agents (firms)	FOCUS - preferential attachment; - flow of energy; - local interactions	FOCUS - path dependent; - non-linear	MARGINS	Emergence of: - firm rules/ protocols; - clusters
Urban Computational Modelling INTEGRATED - simple rules; - iterations; - feedback loops; - variables; - fitness	INTEGRATED - building blocks	INTEGRATED - dynamic interactions;	INTEGRATED - bifurcations; - multiple scenarios	INTEGRATED - mathematical regularities	Emergence of: - attractor states
Landscape Urbanism THEORIZED - feedback loops - time	MARGINS	FOCUS - capturing flows; - unfolds via interactions	FOCUS - open scaffolds; - indeterminate - affordances	MARGINS	MARGINS

TABLE 2.1 Comparison of Urban Research agendas in relation to CAS Defining Clusters

As a still nascent area of investigation, there remain significant ambiguities in how CAS phenomena are understood, appropriated, and interpreted by those undertaking urban and spatial research. This paper attempts to address some of these ambiguities: differentiating between the mechanisms behind emergent processes, the contexts wherein complex processes play out, and the structural outcomes of these processes. The diversity of urban approaches outlined above does not imply that any are flawed or that they misappropriate CAS: it simply means that there is no unified set of principles that corresponds with urbanism and planning discourses engaging CAS: either as model or as metaphor.

CAS research in urbanism is predicated upon the idea that imported frameworks and metaphors from one discipline provide new insights and innovations in another: revealing previously hidden perspectives and knowledge. Nonetheless, an appropriation of sketchily grasped notions outside of one's area of expertise runs the risk of masking weak concepts behind trendy terms: jargon that is easily appropriated but less easily understood. Doreen Massey, discussing the pitfalls of cross-disciplinary appropriations (particularly from physics) observes that, *'as provocations to the imagination they may be wonderfully stimulating; as implicit assertions of a single ontology they need justifying; as invocations of a higher, truer science they may be deeply suspect'* (1999, page 264).

Nigel Thrift (1999) voices similar scepticism, noting that CAS has been co-opted as a kind of 'commodity' within academic debate. He nonetheless acknowledges the potential of CAS to open up new modes of inquiry, 'clearing old ground and creating new'. More recently, Angelique Chettiparamb suggests that the appropriation of CAS into planning theory remains unconvincing. She notes that metaphors have been appropriated both with little concern for the fidelity of the principles being transferred, and little understanding of how these principles might be meaningfully re-conceptualized. She states:

Re-conceptualization must be taken further to achieve three objectives: to explore the connotative meanings associated with complexity theory as revealed in different source domains from which the theory originates [...] to undertake a fuller and more detailed exploration of the abstracted features so as to yield the relational structure within the abstraction in finer detail; and to undertake empirical work to detail out how the imported structural mapping plays out in the new target domain, thereby yielding new insights relevant to this domain, while changing and contextualizing the received concepts. (Chettiparamb, 2006, page 82)

In providing a comprehensive overview of the links between the source domain of CAS and the various target domains of urban theory, I hope to clarify trends, propensities, and blind spots. Of interest here is how some streams of inquiry remain isolated from one another in terms of the key perspectives they respectively draw upon.

To summarize, we can observe that Computational Geographers – biased by programming methodology - focus upon agent rules, with these rules playing out within abstract computational contexts. Meanwhile, Relational and Assemblage Geographers – guided by interests in human interactions, history and the nature of contingent flows – focus upon forces mediating the selection context, considering both the philosophical and epistemological implications of complexity as it affects how we construct and reconceive the urban 'object' as multiple, contingent, thick and overlapping urban 'relations'. Finally, Communicative Planners - championing an emancipatory political agenda that aims to empower actors previously marginalized by top-down forces – focus

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on the 'bottom-up' heterogeneity of CAS agents which, for them, are the human actors involved in planning contexts..

More specifically, the ways in which 'phase space' or 'spaces of possibility' are implicated in the discourses varies significantly. Computational Geographers take stock of statistical patterns manifesting in phase space, Relational/Assemblage theorists conceptualize and trace historical trajectories brought about within configurations of phase space, while Landscape, Tactical, and Incremental Urbanists (all operating as spatial practitioners), seek to activate phase space.

Key differences also pertain to how agents are conceptualized. Computational Geographers propose rule-based cellular agents within their models; Evolutionary Economic Geographers locate agents at the firm level; Communicative Planners consider various stakeholders to be the relevant agents; and Incremental Urbanists consider individual units of built fabric as the agents. All are interested in how agents evolve over time to become more 'fit', but some consider topological regularities of agent aggregation, while others disregard this factor.

Finally, we observe strong disconnects in how concepts of emergence are framed. For Computational Geographers, emergence pertains to mathematical manifestations of power-law regularities. For EEG, it pertains to physical patterns of economic clusters. For Communicative Planners, it pertains to politically empowering conceptual consensus emerging through dialogue. For Assemblage Theorists, it pertains to the ontological nature of things as stabilized but temporary groupings of entities, (physical, political, social, etc.), that come together in highly contingent forms.

Such variations illustrate how urban research may appear at odds due to different epistemological and ontological assumptions regarding CAS. Moving ahead, it may be of interest within a given research stream to take a closer look at aspects of complexity that appear faded out within each particular frame of reference. With greater clarity regarding the starting points and premises of research, it should become easier to identify both the gaps and the areas of common ground between streams: fostering enhanced dialogue and enrichment of our overall understanding of spatial and urban complexity.

3 Situating Complexity in Contemporary Landscape Practice

Abstract

This paper examines general principles of Complex Adaptive Systems (CAS) theory and how these are incorporated into urban and planning studies. CAS theory offers analytical tools that help unpack the dynamics of non-linear systems - ones that are open to energy input and operate far from equilibrium. In this paper, I identify 'hallmark' features of CAS, then relate these features to the specific contribution of Landscape Urbanism (LU) within the CAS/Planning discourse. Many LU practitioners are engaged with research that is highly informed by a CAS ontology. However, as this work is mostly disseminated within design journals, it remains 'under the radar' within the broader academic literature that considers the links between CAS and urbanity. Nonetheless, LU operationalizes methods central to CAS – by creating environments able to self-organize and evolve in light of indeterminate and shifting forces. By providing a survey of several key LU projects and their organizing principles, I argue that LU methods offer unique and helpful insights for operationalizing CAS principles within the broader urban context. I conclude with a brief discussion on implications for urbanism and planning.

Introduction

Over the past few decades, Complex Adaptive Systems theory has been exerting a growing influence on planning and urbanism (Batty, 2007a; Boelens and Roo, 2016; Hillier, 2008). CAS offers analytical tools that help unpack the dynamics of non-linear systems - ones that are open to energy input and operate far from equilibrium. In this paper, I suggest that Landscape Urbanism (LU) offers substantive insights for spatial practitioners wishing to engage CAS principles. LU explores methods whereby complex dynamics that enrich urban life are channelled and instigated directly in space through interactions played out in physical form. Rather than trying to *control, analyse, theorize, communicate, model or predict* complex factors, LU strives to *engage and deploy* complexity on the ground. This deployment involves first *recognizing* that certain situated territorial conditions can more effectively afford the possibility of complex forces self-organizing, and then *activating* these territorial conditions.

I argue that LU offers a unique perspective on incorporating principles from CAS into design and planning methodology. In what follows, I will argue that Landscape Urbanists employ the language of CAS (emergence, indeterminacy, feedback, flows, evolution, etc.), see urban environments as complex systems driven by a range of overlapping forces and flows, and perceive their interventions as contingent and subject to historical unfolding. Projects adopt, *'the language of flows, shifting*

*populations, succession, patches, dynamic systems, matrices, self-organisation, instability, etc., [...
where...] systems are dynamic, fluid, unstable, complex and indeterminate'* (Thompson, 2012, page 14). These LU principles echo those advanced in CAS theory (Prominski, 2005).

While a discussion of the ontological parallels between LU theory and CAS theory is interesting in and of itself, it is also relevant in terms of a broader planning debate: the recurrent theme pertaining to the gap between the *theory* of planning versus the *object* of planning. While there has been a concerted effort to integrate CAS perspectives into theories of planning (Sengupta et al., 2016), much less work has been produced on how CAS perspectives might influence or advance the *object* of planning – the material environment and how this might evolve over time. Yet there is a growing sentiment that speaks for the need to re-engage with the material conditions of the spaces we plan (Binder, 2011; Boelens, 2006; Harrison, 2013; Lord, 2014).

Notwithstanding this call, engaging with the open-ended and indeterminate qualities of CAS in the context of material settings (which we perceive of as fixed) is far from intuitive. By surveying a number of key LU projects, I demonstrate how Landscape Urbanists engage with urban materiality in ways that might provide a means forward. Here, the material conditions of situated sites are framed as being open-ended, plastic, and contingent - a 'baroque' materiality (Anderson and Wylie, 2009; Jones, 2014) activated, in part, by how users encounter and engage it. In LU projects, material form, rather than being conceptualized as a fixed and defined entity, operates in modes where it can *'be thought of as containing modalities of potentiality or possibility'* (Anderson and Wylie, 2009, page 330). These modes of potentiality are easily situated within a CAS ontology, wherein matter remains concrete and specific, yet still malleable and plastic – an environment that is open-ended and creates affordances for contingent, non-linear futures.

The paper is divided into five sections. Part One provides a brief introduction to CAS principles. Part Two considers how CAS has been defined in academic literature and then distils key common defining attributes. These core attributes are then considered as 'centering' various research streams in planning that draw from CAS. Part Three discusses LU work as unique amongst these streams by virtue of its situatedness within the material strata of the city. It looks at LU's history and theory, and at how its core conceptual themes resonate with key CAS attributes. Part Four then reviews a number of Landscape Urbanism projects, framing their concepts and execution in terms of how these relate to CAS. The paper concludes with considering the broader implications of LU methods for planning and urban design.

§ 3.1   Part 1: Complexity Theory - General Principles

Complex Adaptive Systems theory (CAS) is a relatively recent addition to our way of understanding, conceptualizing and analysing relationships that are able to generate structure. Over the past few decades, research into the implications of CAS - originally spearheaded at the Santa Fe Institute - have grown and intensified. One of the key outcomes of this research is the understanding that CAS systems are ubiquitous: that the underlying dynamics governing one CAS system can be transferred when reflecting upon another (Heylighen, 2011b; Kauffman, 1996). Today a CAS perspective is becoming an increasingly fruitful way to analyse and discuss problems in an array of disciplines be they economic, political, or cultural. Cities are no exception, with CAS informing a diverse range of urbanism and planning discourses (Batty, 2007a; Chettiparamb, 2006; Inness and Booher, 1999; Portugali, 2000).

A full overview of Complex Adaptive Systems lies outside the scope of this paper, but can easily be accessed in work produced by others (see for example Capra, 2004; Holland, 1995; Sawyer, 2005). However, a basic outline will here serve as an introduction. CAS theory engages with an examination of systems that are energetically open and manifest emergent structure without need for top-down control. CAS are composed of basic, interacting parts (agents), which process energy or resources (available through the system's dissipative boundaries), and gradually evolve more effective internal organization due to feedback processes (Heylighen, 1999; Holland, 1995). While agents are not necessarily intelligent, they employ general Darwinian mechanisms – variation, selection, and retention – in order to gradually select for behaviours that increase their fitness within the system. During this process, agents have the capacity to interact and steer each other's behaviour, leading to global emergent or aggregate behaviours that are not predictable based upon the individual agents. Here, *emergence* refers to the ways in which novel global behaviours appear that are neither predictable nor reducible to the inherent properties of the agents that produce them. Systems are thus described as being *'bottom-up'*, since higher levels of order are predicated upon interactions at a lower level. Flocking birds, booms and busts on the stock market, and even the organization of the World Wide Web can be seen as the result of complex adaptive dynamics.

CAS theory is considered an offshoot of General Systems and Cybernetic approaches (Gell-Mann, 1994). However, CAS differs from these in subtle but significant ways. General Systems Theory, while concerned with interactions, focuses upon closed systems that can be optimized towards a singular equilibrium. Cybernetics, while considering open systems, explores systems governed by negative feedback, which tend to dampen and stabilize system changes. CAS systems, in contrast, although primarily internal and bounded are also *dissipative:* open to inputs, energy, matter, and information from the surrounding environment that in turn fuel internal system dynamics (Prigogine and Stengers, 1984). This allows them to seemingly violate the second law of thermodynamics – whereby CAS generate *emergent* structure. Here, the system's openness to energy inputs, combined with responsiveness to positive feedback, sets in motion dynamics whereby small input changes are amplified in ways that cause entirely new structures to arise. CAS can thus unfold in multiple trajectories in accordance with these small changes, leading to manifestations that are contingent and based on historical conditions.

§ 3.2 Part 2 - Defining CAS

To date, there is no 'authoritative' definition of what constitutes a Complex Adaptive System. Notwithstanding, several well cited researchers including Gell-Mann, (1994); Holland, (1995); Arthur et al., (1997); Levin, (1998); Cilliers, (1998); Heylighen, (1999); (Taylor, 2002);Mitleton-Kelly, (2003);Dopfer et al., (2004); Martin and Sunley, (2007); Anderson, (2008); have advanced lists of key CAS attributes. In Chapter Two, I compiled a summary of recurring overlaps between these definitions, identifying the 'consensual' characteristics of CAS. This suggests that CAS are at essence:

— *organized through flows and interactions;*
— *subject to non-linear and historical processes;*
— *adaptive and evolutionary;*
— *comprised of a diversity of agents;*
— *described by scale free/nested mathematical hierarchies; and*
— *characterized by self-organizing and emergent features.*

Figure 3.1 illustrates the relationships of these six defining attributes of CAS, and how these pertain either to aspects of the *Context, Processes, or Outcomes* of Complexity Dynamics.
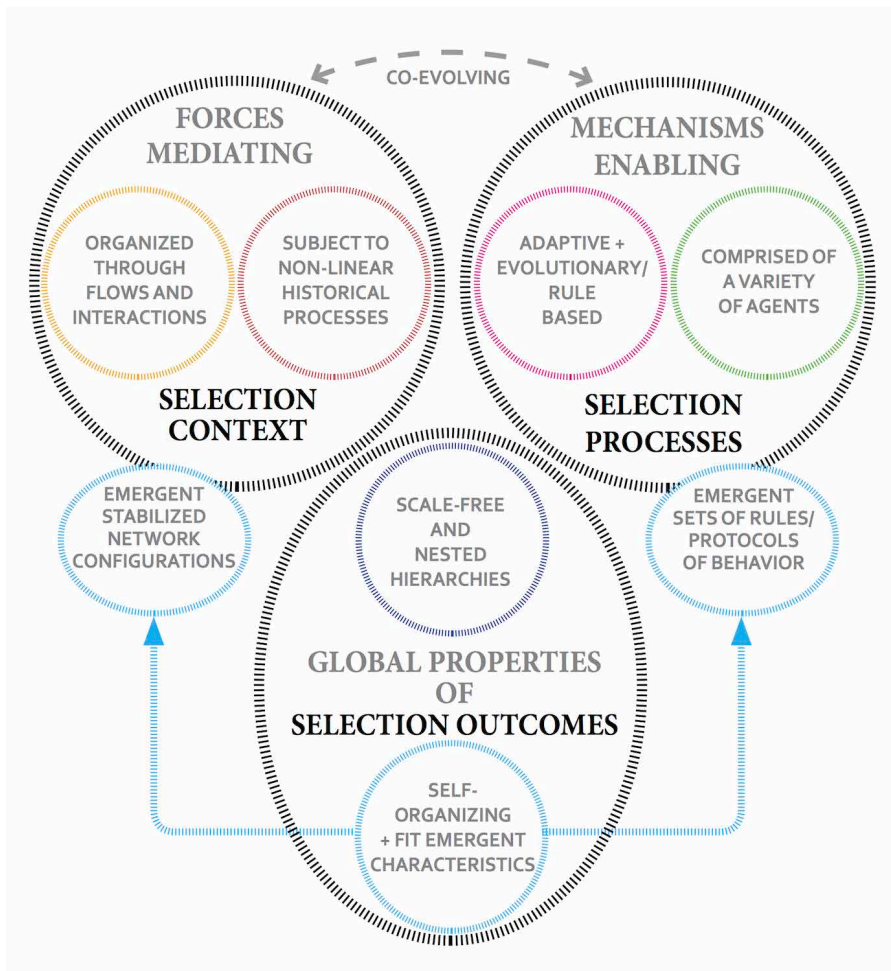
FIGURE 3.1 Defining CAS attributes

CAS is a broad realm of study, with different research drawing from CAS perspectives in different ways. This categorization of CAS aspects can be employed as a framework to consider how CAS is conceived within various research streams. Thus, while not ignoring other attributes of CAS, various research streams appear 'centered' upon one or two particular aspects of Complexity. For example, Computational Geographers pay close attention to scale-free and fractal manifestations of CAS, whereas Communicative Planners are more concerned with the fact that CAS involve a variety of interacting agents. Relational Geographers pay attention to the flows and interactions of CAS, while Assemblage Theorists are drawn to its non-linear, historic and contingent nature. Depending upon the stance, different properties of CAS dynamics (as defined above) tend to become more or less central to the research.

Each of these ways of engaging CAS provides its own set of insights, but depending upon the 'lens', different research aims ensue. Relational and Assemblage thinkers employ complexity

as an interpretive device that assists in *theorizing* about the city. Communicative Planners use complexity theory in order to consider how to stage an equitable dialogue *regarding* the city. Finally, Computational Geographers employ CAS as a means of *forecasting* and *modelling* potential cities.

Despite the breadth of these approaches, I wish to highlight that there is an overall *lack* of theorizing that pertains to how one might deploy and enact complex processes of the urban *on the ground*. Thus, while many geographers focus upon how complex flows of resources and infrastructure are key to understanding how cities evolve, little has been theorized about the material strata of the city that enable these flows to become grounded. While there is some literature on flows coalescing where they become overlapping and 'thick' (Read, 2007b), there is less that considers the kinds of settings that are 'primed' to provide the affordances for these flows to be expressed in material form. In what follows, I consider this means of activation from the perspective of LU theory and practice. To do so, I begin with a brief introduction of Landscape Urbanism as a field of inquiry.

§ 3.3 Part 3: Landscape Urbanism History and Principles

*Landscape's being is constituted through the unfolding practices that surround it. Its presence is not engendered by features in the landscape itself but by the various ways it is called forth and put to task. In this sense the only thing that ever **is** is the practices that make it relevant. While it appears as a definable material space, its materiality is constituted by the totality of possible performances immanent within it: the constitutive potential of the unfolding labyrinth. (Rose, 2002, pages 462–463)*

Landscape Urbanism grew from the reflections of a number of practitioners based at the University of Pennsylvania, the Harvard Graduate School of Design, and the University of Illinois, Chicago. It has been advanced primarily through their projects as well as those coming out of several Netherlands based firms. The first seeds of the LU discourse can be found in two highly influential *Parc de la Villette* competition entries. Both the offices of Bernard Tschumi, as well as that of Rem Koolhaas' OMA, generated proposals that explored indeterminate futures: stressing the creation of strategic infrastructures that could accommodate unknown potentials. These projects positioned the emerging Landscape Urbanism discourse as:

Less about the construction of finished works, and more about the design of 'processes', 'strategies', 'agencies', and 'scaffoldings' - catalytic frameworks that might enable a diversity of relationships to create, emerge, network, interconnect, and differentiate. (Corner, 1997, page 102)

A series of works, subsequently executed by OMA, West 8, Field Operations, Stoss, and Mathur/da Cunha (particularly in the Downsview Park and Fresh Kills Competitions), continued to expand upon these themes. In addition, two influential texts, *Recovering Landscape* (1999b) and *The Landscape Urbanism Reader* (2006) helped to disseminate key ideas within the Landscape Architectural community.

These texts expressed how LU involved a break from traditional landscape interests in the generation of scenographic and pictorial settings. Here, a conceptual distinction is made between *landskip* '*landscape as contrivance, primarily visual and sometimes also iconic or significant*' and *landschaft* '*landscape as an occupied milieu, the effects and significance of which accrue through tactility, use,*

and engagement over time' (Corner, 1999: 154). The actualization of programs is something that is *performed* in space and time, through actors that engage with the area.

This performance takes place within a spatial arena that not only permits but also affords a range of potentials. This concept of open-ended potential is different from the modernist notion of 'universal space'. In the modernist conception, spaces were left open to be adapted and appropriated for a wide range of uses: but this was done in a neutral manner, where compositional (rather than operational) features of space were the focus of design. LU, by contrast, does not just leave a space open, but also aims to increase a space's *capacity* to foster the emergence of contingent events. Thus, *'the surfaces they [landscape urbanists] see are not just visual patterns but more mutable and thickened topographies, systemic and alive'* (Wall, 1999, page 247). In order to provide these mutable settings, LU practitioners speak of 'seeding' an area, 'irrigating' a territory or 'staging' the ground - all alluding to an active and catalysing engagement with the territory that anticipates and prepares the ground for possibility - while still maintaining an open-endedness in terms of which future possibilities are actualized (Corner, 1998).

This framework leads to new techniques of analysis, representation, and intervention that capture the '*fluid, process driven characteristics of the city*' (Corner, 1999b, page 30). LU thus considers both the importance of understanding flows and designing to enable these flows to come together, but it further considers the preparation of the territory where these forces coalesce. Here, the concept of 'staging' or the creation of 'affordances' is significant. Affordance (Gibson, 1986) describes the capacity of designed objects or environments to *invite* multiple kinds of appropriations – in other words, to manifest in different 'states', in accordance with different kinds of uses or engagements. The choice of which state to manifest rests upon the kinds of imbricated relationships activated by users (Withagen et al., 2012). That said, not all sites offer equal affordances to shift into different regimes of behaviour - if too specific, territories do not have the plasticity required; if too open-ended, they become neutral modernist space - with little capacity to meaningfully support any programmatic specificity.

This interest in affordance echoes both the notion of phase space (Jones, 2009), and that of 'plasticity' (Van Dyke, 2013), as means with which to affirm the agentic capacity of the material, while conceptualizing this in ways that circumvent the pitfalls of environmental determinism.[12] Instead, affordances, phase space, and plasticity each engage with the idea (also central to CAS) that material entities have certain capacities that are virtual and contingent (DeLanda, 2005) – but that these are activated and manifested under particular circumstances. That said, material affordances are not completely open-ended – there are still limits, and the way in which the capacities of material form are 'called forth' is through practices that involve the agency of other actors (Rose, 2002). Here, the environment elicits (rather than controls) but is then shaped and stabilized in accordance with situated needs. Jones describes this process, whereby:

…like phase space, plasticity does not license multitudinous open-ended possibilities: it works within the existing parameters of material possibility, but unlike topology, deformations reshape the whole and original shapes cannot be returned to.' (2014, page 2600)

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12   In Chapter Five I describe Jones' concept of 'Phase Space' and how this concept from physics relates to the material potential of a given environment.

By creating a range of environments that support programmatic potential, Landscape Urbanists accept the future as non-linear, open-ended and contingent, but still *act* to provide meaningful material territories that can be appropriated and modified when contingent forces coalesce. Here, the design of spaces is replaced by the design of affordances:

On the face of it this may seem like a contradiction in terms: the deliberate design of spontaneous interactions. But it is not. Physical environments have something to offer their users. An environment provides 'possibilities for action' or 'affordances'. [...] our designs depend on a single physical intervention to create multiple affordances, that is various possibilities for action. (Rietveld and Rietveld, 2011, 33)

A growing body of LU work thus engages an acceptance of process, evolution, and unknown site dynamics, with the actualization of site features occurring in accordance with non-linear interactions. Sites and flows interact such that uses emerge rather than being zoned or planned explicitly. Projects investigate the provision of, '*a directed field for the occupation of the site over time:* a *kind of loose scaffold that supports the adaptive ecology of urban life ... a system of movement, service and support that give direction to program without over-determining the use or meaning of individual space*' (Allen, 2002, page 125). LU thereby seeks to:

1 Create catalysing environments that adapt to unknown futures;
2 Develop overlapping, interacting, organizational hierarchies;
3 Leverage infrastructure and flows;
4 Allow for non-linear, open-ended, and contingent transformations;
5 Foster process driven, emergent outcomes;
6 Activate bottom-up tactics and strategies to generate use.

Table 3.1 illustrates the parallels between these objectives and the characteristics of CAS, highlighting the correspondences between CAS and LU, as well as their distinction from modernist planning approaches. The contrasts emphasize the fundamental ways in which LU positions itself in new territory. For example, LU 'plans' are not really 'plans' in the normal sense of a graphic depiction. Often the drawings are not of things, but of sequences driven by processes, indicating these processes rather than the forms associated with them. Accordingly, graphics are often indeterminate. OMA's drawing of Downsview Park, for example (in collaboration with Bruce Mau), utilizes an array of multi-coloured and multi-scaled dots to suggest the potential texture, rather than the specific compositions, of spatial programming. Here, process and uncertainty is considered an integral part of the plan.

CAS Characteristics	Landscape Urbanism Strategies	Modernist Planning
Adaptive and evolutionary	Create catalyzing environments that adapt to unknown futures	Master plans, specific representations, imagined futures.
Described by scale free/nested mathematical hierarchies	Develop overlapping, interacting, organizational hierarchies	Single compositional plane of elements
Organized through flows and interactions.	Leverage infrastructure and flows	Built physical 'objects' organize and generate relationships
Subject to non-linear and historical processes	Allow for non-linear, open-ended, and contingent transformations over time	Optimized for planned/known outcome
Characterized by self-organizing & emergent behaviours	Foster process-driven, emergent outcomes	Characterized by fixed/static patterns
Comprised of a diversity of agents	Activate bottom-up tactics and strategies to generate use	Implemented through top-down control.

TABLE 3.1 Landscape Urbanism strategies compared to CAS and traditional planning practices

While it is certainly true that modernist planning also considered the role of time and process this, for the most part, was not what drove the plan. 'Master plans' of the modernist period, depicted desired end-states. These were envisioned, with graphics that assigned programs, quantities, zones, hierarchies, etc. This is not to imply that there were no urban theorists who highlighted ways of embracing process within their practices. Christopher Alexander, for example, focused on the sequential and generative building of a city (1979). That said, these thinkers were more the exception rather than the rule. More often, urban thinkers who employed notions of systems and process - for example, Jay Forrester, (1969), in his *Urban Dynamics* - were typically looking to create optimized scenarios or, in some way, to *control* process, rather than *embrace* process as a generative tool. Table 3.1 thus sets up dichotomies (which tend to polarize more than is perhaps accurate), but it nonetheless provides an overall 'flavour' of the tone of master-plann thinking that, until recently, has dominated the circles of practice. Here, as a pragmatic driver, clients tend to insist upon graphic scenarios depicting future 'realities' - with which they can then go to the bank and secure loans to achieve their visions.

§ 3.4   **Part 4: Landscape Urbanism Case Studies - Overview and comparisons**

'Change is not just willed by us humans but comes about equally through the materialities of the world in which we are just a part, and which, through habit, we encompass in the everyday, ever changing, assemblage of thought, intensity and matter.' (Dewsbury, 2011, page 152)

I wish to now provide an overview of six projects that adopt a Landscape Urbanist perspective, highlighting their relationship to CAS. The first of these projects (from the Parc de la Villette competition) are considered important precedents for LU thought. The next two, Schowbergplein and the Highline are considered seminal LU works. A fifth, Almere, Oosterwold, though not typically referenced in LU publications, is included due to its close alignment to core LU principles. A sixth project is the OMS stage in Winnipeg, which I include because of my direct personal involvement conceiving the work.[13] This final project is an architectural one situated within a landscape context where the LU principles of indeterminacy and affordances are central to its concept. By including this work, I hope to bridge the discussion from that of landscape into that of architectural built fabric. The projects surveyed thus include:

— Parc de la Villette, Paris: 1983 Competition entry (OMA)
— Parc de la Villette, Paris: 1987 (Tschumi)
— Schouwbergplein, Rotterdam: 1996 (West 8)
— High Line, New York: 2009 (Field Operations/Diller Scofidio)
— Almere, Oosterwold: 2015 - launching construction (MVRDV)
— OMS stage, Winnipeg: 2010 (5468796 Architecture)

For each project, I provide a brief description (more detailed project documentation is easily available elsewhere), a project image that highlights relevant features, and an evaluation matrix. These matrices compare each of the Project's key concepts with the features of CAS and LU strategies outlined in Table

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13   A project for which I was part of the design team

1. Together, these matrices provide a way to consider each project's relationship to CAS dynamics in a systematic manner. The commentary in the matrices is based upon a variety of criteria: the architect's commentary on their own projects, reviews of critical discourse on the projects, as well as my own on-site observations (I have visited all of the built projects, including touring Almere, Oosterwold, with the planner-in-charge of coordinating the development). I conclude with an overall comparative matrix that surveys which aspects of CAS are most clearly integrated with LU projects.

§ 3.4.1   Parc de la Villette (competition entry) – OMA

For this highly publicized but unbuilt competition entry, Rem Koolhaas developed open-ended linear strips of juxtaposing programs within the park, where the heterogeneous nature of the strips could support a range of activities, but actual use would become entrenched in response to evolutionary processes. Koolhaas' strategy was to create affordances for a breadth of activities, and then allow each strip to 'compete' and 'evolve' into appropriate programs. By creating a high number of juxtapositions, he aimed to create opportunities for synergies, so that if a program was unsuccessful in one site configuration, it might nonetheless find traction if set in another relationship to its surroundings. The manner of rendering the site in the competition entry is deliberately cartoon-like rather than realistic, implying that the drawings are 'suggestive' of potentiality rather than fixed as future givens. The final site configuration is open-ended, and subject to ongoing processes. Koolhaas states that the project investigates, *'how to orchestrate on a metropolitan field the most dynamic coexistence of activities x, y, and z and to generate through their mutual interference a chain reaction of new, unprecedented events'* (Koolhaas and Mau, 1995, page 921)

	LA VILLETTE / OMA EVALUATION MATRIX	
CAS PRINCIPLE:	**LU Strategies**	**Observed Parallels with CAS**
Adaptive and evolutionary	Create catalyzing environments that adapt to unknown futures	YES. Strips are designed to accommodate change and a wide array of explorations of program types
Described by scale free/nested mathematical hierarchies.	Develop overlapping, interacting, organizational hierarchies	SOMEWHAT. Site is organized using seven overlapping organizational systems that interact. Each level organizes infrastructures of different scales/types; no explicit link to mathematical scale–free systems
Organized through flows and interactions	Leverage infrastructure and flows	YES. Layers channel different kinds of flows. It is the interactions of these layers that drive the specific evolution of the strips
Subject to non-linear & historical processes	Allow for non-linear, open-ended, & contingent transformations	YES. The site can evolve into entirely different distributions of programs in accordance with chance historical events, changing economics, etc.
Characterized by self-organizing & emergent behaviors.	Foster process driven, emergent outcomes	YES. There is no final master plan. The design is intended to enable emergent processes rather than being a plan of a final project.
Comprised of a diversity of agents	Activate bottom-up tactics & strategies to generate use	YES. The Strips act as 'agents' activated by site forces that steer evolution. The scheme incorporates a diverse, large number of strips to afford the largest number of evolutionary explorations.

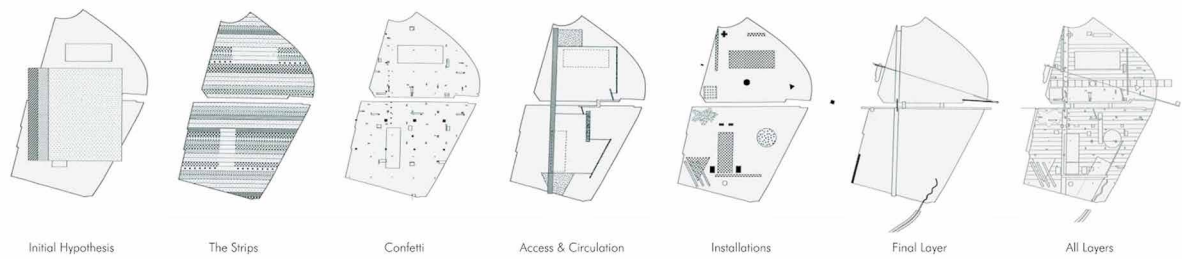TABLE 3.2 La Villette/OMA strategies related to CAS principles

FIGURE 3.2 La Villette infrastructural layers (image retrieved from OMA website)

§ 3.4.2 Parc de la Villette, (Tschumi)

Following OMA's unbuilt project, we go to Bernard's Tschumi's successful entry for the Parc de la Villete competition. Tschumi's stated goal was to *'construct a complex architectural organization without resorting to traditional rules of composition, hierarchy and order'* (1996, page 198). His scheme adopts many strategies similar to that of the OMA entry, including organizing the site through a strategy of infrastructural layering. These layers include: 'points' – follies at randomly staged intersections that can accept different programs and permit unforeseen potentialities to emerge; 'lines'- patterns of movement and circulation that produce site flows; and 'surfaces' – fields of open space that can be appropriated for various outdoor programming. The follies were a result of Tschumi's decision to shatter the 'built program' component of the project brief into a collection of independent, open-ended and mutable structures. This tactic is intended to, *'provide the site for opportunities and spatial experimentation: a place to trigger response and continuous development over time'* (Diamond, 2011, page 25). Thus, both of the la Villette projects:

Shattered the logic of causality replacing it with an aleatoric logic of chance, always allowing possible unusual connections. Landscapes emerged not from the organisation of spaces and volumes but from collections of fragments in fluid fields of change, a dynamic web of interconnections realised through layers and links (actual and virtual). (Armstrong, 2004)

FIGURE 3.3 La Villette Follies –Program split into individual open-ended elements (Image by Tschumi Architects)

CAS PRINCIPLE:	LA VILLETTE / TSCHUMI EVALUATION MATRIX	
	LU Strategies	Observed Parallels with CAS
Adaptive and evolutionary	Create catalyzing environments that adapt to unknown futures	YES. Follies are intended to accommodate change and a wide array of explorations of program types: fields are also open-ended and adaptive.
Described by scale free/nested mathematical hierarchies.	Develop overlapping, interacting, organizational hierarchies	SOMEWHAT. The site is organized using three overlapping organizational systems that interact. Each level organizes infrastructures of different scales/types: ne explicit link to mathematical scale-free systems
Organized through flows and interactions	Leverage infrastructure and flows	YES. Layers channel different kinds of flows. It is the interactions of these layers that drive the specific evolution of the follies
Subject to non-linear & historical processes	Allow for non-linear, open-ended, & contingent transformations	SOMEWHAT. It was intended that the programs of the follies would evolve, but as executed these are much more static. However, the project may well change in the ensuing decades, and change is not precluded.
Characterized by self-organizing & emergent behaviors.	Foster process driven, emergent outcomes	SOMEWHAT. The overall framework of the site is fixed, although programs of fields and follies are intended to emerge. The execution is both more rigid and less suggestive of evolutionary options – being much less dramatic than the theoretical ambitions.
Comprised of a diversity of agents	Activate bottom-up tactics & strategies to generate use	YES. The Follies in this case act as the 'agents' that respond to the site forces and evolve. However, Tschumi limits the number of these agents compared to Koolhaas. Their placement, while random, is less conducive to capturing site forces, as the number of intersections are limited. Finally, they are quite rigid, meaning that options for accepting shifting programs are limited.

TABLE 3.3 La Villette/Tschumi strategies related to CAS principles

§ 3.4.3   Schouwbergplein, West 8

The next seminal project in the 'cannon' of LU is the redevelopment of Schouwbergplein in the Netherlands. The project is intended to *'change its identity like a chameleon changes colour'* (West 8 Website). The plaza is animated and altered by the interaction of site infrastructures that are in some way mutable. These infrastructures include: four lighting mastheads; a tent pole infrastructure that permits various canopy configurations; shifts in the ground plane treatment that vary in warmth and texture to suggest different configurations at different temperatures; and water elements that, at times, turn portions of the plaza into a wet play area. These elements offer both flexibility and the suggestion of affordances: inviting the plaza to be appropriated for activities and installations of varying types and scales. The four lighting masts can be reconfigured by the public into a huge number of permutations – ranging from the condition where all masts form a horizontal canopy, creating a more intimate site, to a configuration when all four are fully raised to form a vertical wall, suggesting a much taller vertical outdoor room. At night, the reconfiguration of the masts leads to an array of lighting effects, spotlighting certain areas while providing diffuse light in others. These permutations provide the site with a range of perceptual scales and atmospheres. The strategy allows otherwise neutral ground to be 'prepared' to host an array of programs, responding to daily, seasonal, and user preferences.

Schouwburgplein is a permanent urban infrastructure design to accommodate a succession of 'dynamic temporal' activities ranging from skateboarding events to flee-market transaction [...] the genius of the work lays both in its ability to catalyze transformative shifts within each urban condition that affects normalized programmatic components. (Okigbo, 2009, page 134)
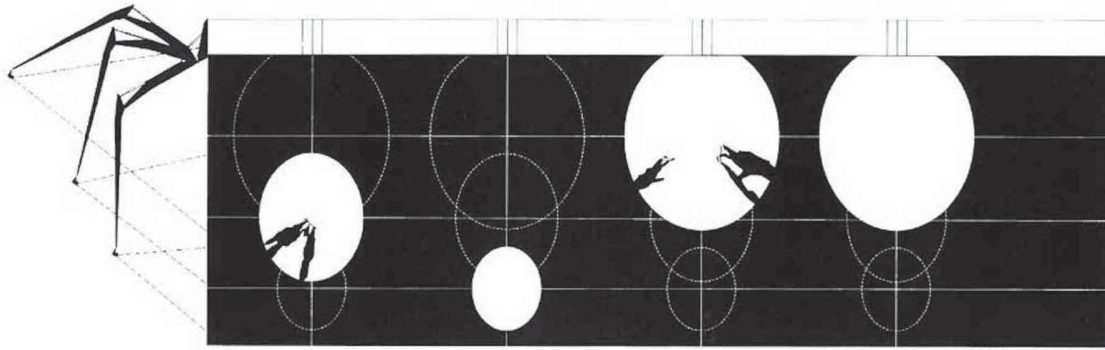
FIGURE 3.4 Diagram illustrating permutations of lighting masts (Image by West8 Architects):

	SCHOUWBERGPLEIN EVALUATION MATRIX:	
CAS PRINCIPLE:	**LU Strategies**	**Observed Parallels with CAS**
Adaptive and evolutionary	Create catalyzing environments that adapt to unknown futures	SOMEWHAT. Lighting Masts can be continuously reconfigured, though their range of movement possibilities is limited.
Described by scale free/nested mathematical hierarchies.	Develop overlapping, interacting, organizational hierarchies	SOMEWHAT. The site is conceived as a series of layered, interacting parts that support particular uses dependent upon the nature of their permutations and relations; no explicit link to mathematical scale–free systems
Organized through flows and interactions	Leverage infrastructure and flows	YES. The site is activated at different times and seasons according to user needs. The surface plaza is easily reconfigured to accommodate a wide range of activities.
Subject to non-linear & historical processes	Allow for non-linear, open-ended, & contingent transformations	SOMEWHAT. The site elements do not evolve, but their day-to-day manifestation changes according to random user events. Thus a shift in the mast configuration (controlled by a random use) leads to the site having entirely different atmospheric conditions.
Characterized by self-organizing & emergent behaviors.	Foster process driven, emergent outcomes	YES. The site's design provides a setting for emergent possibilities of use, with site infrastructure offering the capacity for these uses to be hosted. There is no pre-determined notion of how the site should be configured.
Comprised of a diversity of agents	Activate bottom-up tactics & strategies to generate use	MINIMALLY. The design is flexible, but is not really an agent-based system. There are a variety of infrastructural elements that are flexible, but their range of configurable options are limited. That said, the site does support a wide range of uses due to the number of permutations enabled.

TABLE 3.4 Schouwbergplein strategies related to CAS principles

§ 3.4.4 High Line, New York (Field Operations)

The designers of New York's High Line project describe it as, '*a flexible, responsive system of material organization where diverse ecologies may grow*'.[14] The architects generate this flexibility by conceiving the ground as a continuous landscape of experimental permutations, providing a sampling of various treatments and densities that thereby support different kinds of uses and programs. The specific

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14   Project description, Architect's website – Diller Scofidio + Renfro

nature of these programs is left open-ended, with the site strategy involving the creations of different conditions that might be activated in accordance with the surrounding contexts (and the forces these contexts generate). Specific regions of the High Line therefore become activated in response to the specificity of urban intersections, micro-climate conditions, and individual user preferences. There is little focus upon pre-determining the actual nature of site use, and more focus on assuring that the linear band of the High Line undergoes continuous permutations along its length, exploring the iterative possibilities of landscape versus hardscape ratios. The ground plane is conceived as a series of individual strips that can be hardscape, landscape, or 'peeled-up typology' where they form a range of elevated surfaces for occupation. The designers propose a full range of gradients between these individual surface elements. They describe the project as, *'providing flexibility and responsiveness to the changing needs, opportunities, and desires of the dynamic context, [...] designed to remain perpetually unfinished, sustaining emergent growth and change over time.'* (Diller Scofidio + Renfro Website) . While the project suggests an infinite range of variations, these variations are 'frozen' in situ along the length of the High Line, rather than continuously adapting as iterations over time. The flexible nature of the work is thus most apparent in the mutable form of the 'peel–up' typology, where ultimate use is suggestive and evolutionary rather than entrenched.
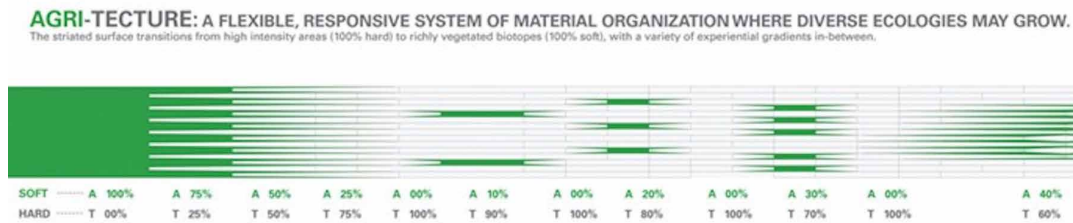

FIGURE 3.5 Parametricized distribution between hardscapes and softscapes (Image credit: Field Operations/Diller Scofidio)
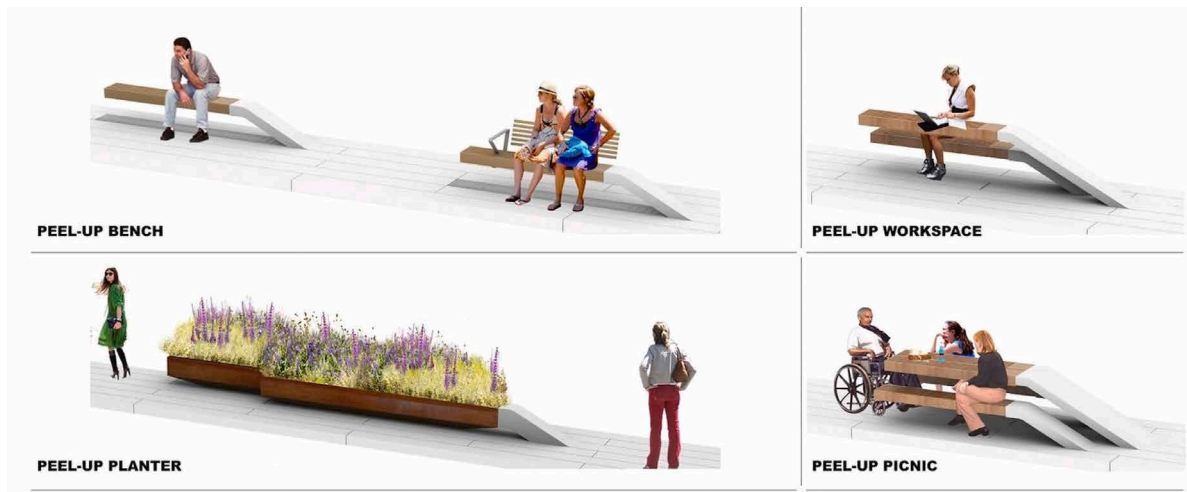

FIGURE 3.6 Peel-up Typology suggesting possible iterations (Image credit: Field Operations/Diller Scofidio)

HIGH LINE EVALUATION MATRIX:		
CAS PRINCIPLE:	**LU Strategies**	**Observed Parallels with CAS**
Adaptive and evolutionary	Create catalyzing environments that adapt to unknown futures	WEAKLY. The designers develop a full range of landscape permutations along the length of the highline, but ultimate locations & relationships are fixed, not really evolutionary.
Described by scale free/nested mathematical hierarchies.	Develop overlapping, interacting, organizational hierarchies	NO. However, there is an interest in setting up a parameterized mathematical organization for the site that involves exploring a breadth of permutations of site conditions, going from maximum to minimum ratios.
Organized through flows and interactions	Leverage infrastructure and flows	YES. Site use is predicated upon juxtapositions between the capacities of the linear strip walkway, and the nature of the surrounding context. The designers foresee a contingent evolution of programs as site synergies emerge.
Subject to non-linear & historical processes	Allow for non-linear, open-ended, & contingent transformations	SOMEWHAT. The use of the planting materials to adds a temporal dimension to the site evolution, but the majority of the physical framework remains rigid once in place.
Characterized by self-organizing & emergent behaviors.	Foster process driven, emergent outcomes	WEAKLY. Most of the site infrastructure, though theorized as 'emergent' is static once executed. Unexpected programs might arise, but the overall form of the project cannot easily transform to accommodate these.
Comprised of a diversity of agents	Activate bottom-up tactics & strategies to generate use	SOMEWHAT. Elements on the ground-plane are conceived as a series of permutations, enabling a series of conceptual configurations However, this range is 'fixed' at the time of construction. The exception is the raised 'peeled-up' surfaces that can shift in use over time depending on how the site is occupied.

TABLE 3.5 Highline strategies related to CAS principles

§ 3.4.5   Almere, Oosterwold: MVRDV

Almere, Oosterwold pushes the envelope in terms of providing an open-ended adaptive framework for planning. Conceived by Dutch Architects MVRDV, the design of Oosterwold parallels key theoretical principles of LU: it uses landscape as a central organizing element, creates open-ended conditions, and conceives of the design as a series of programmatic layers. However, it activates these aspects at the independent plot level, rather than at the overarching site level, leading to new potentials. The agricultural land surrounding Almere is developed as a peri-urban condition, where rural and urban meet. Very few control measures are put in place, other than maintaining overall land-use ratios (18% buildings, 8% roads, 13% public space, 2% water and 59% urban agriculture) and the provision of workable infrastructure (road, energy, sanitation, rubbish collection, public green and urban farming). Each plot owner is responsible for developing their own site, determining the ratios between agricultural and built/programmatic components and also managing the infrastructural requirements for their own plot. At the same time, they must provide affordances for adjacent plots to tie into the system. Voluntary associations of plot owners can come together to create synergetic alliances in the distribution and densities of land use, and the coordination of infrastructure. The architects state:

The area will gradually transform the existing situation to a diverse living and working landscape. Based on the existing qualities and conditions– roads, windmills, water channels, forest ridges, buildings, and the piping-system – it will evolve bottom-up. Freeland develops as a rich assemblage of originality where everything is possible, and where advanced urban planning is also very basic. What could this liberated urbanism look like […] Can we then speak of an evolutionary urbanism? (MVRDV website)
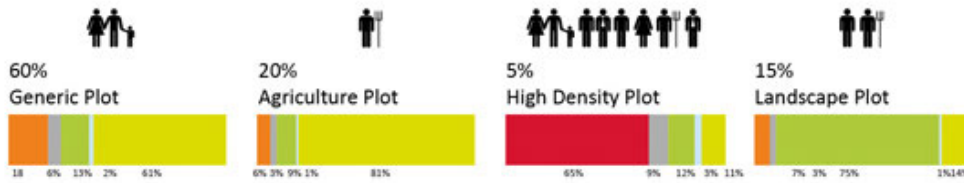
FIGURE 3.7 Individual Plot Ratios: 'Variations on the Generic Plot' (Image Credit, MVRDV)

	OOSTERWOLD EVALUATION MATRIX:	
CAS PRINCIPLE:	**LU Strategies**	**Observed Parallels with CAS**
Adaptive and evolutionary	Create catalyzing environments that adapt to unknown futures	YES. The project is based on an evolutionary model, with the only constraint being the maintenance of overall site use ratios.
Described by scale free/nested mathematical hierarchies.	Develop overlapping, interacting, organizational hierarchies	SOMEWHAT – though not explicitly. The scale of plots is open-ended. The ratio of small, medium and large-scale plots thus may ultimately follow power-law distributions.
Organized through flows and interactions	Leverage infrastructure and flows	YES – though not explicitly. While flows and interactions do not form part of the project discourse, the way plots eventually form into clusters and regions will be dependent upon overall site dynamics and interactions.
Subject to non-linear & historical processes	Allow for non-linear, open-ended, & contingent transformations	YES. The final regional configuration will emerge in accordance with non-linear historical processes. The location of the first owners (the first are locating adjacent to one other to save on infrastructure) will have a non-linear effect on how the site unfolds.
Characterized by self-organizing & emergent behaviors.	Foster process driven, emergent outcomes	YES. There is no top down plan. The development emerges entirely from the bottom-up.
Comprised of a diversity of agents	Activate bottom-up tactics & strategies to generate use	YES. The design of the overall site plan is generating only by what happens at the level of the plots (the agents) there is no master plan, and no infrastructural system. Everything is generated at the plot level, with a large diversity of kinds plots, each exploring spatial possibilities independently.

TABLE 3.6 Oosterwold strategies related to CAS principles

§ 3.4.6 OMS Stage: 5469796 Architecture

The OMS Stage (the Cube) is an open-air performance venue built in an existing urban park. The project replaced an older outdoor stage that had been located on-site. Unlike the previous single-use structure, the design team's response was to build not only a stage, but a malleable infrastructure that could manifest in an array of manners - as stage, as sculpture, as screen, as indoor shelter, etc. The designers were motivated in part by the city's cold winters, and the awareness of the fact that the previous stage - when sitting empty over the long winter months - often appeared forlorn. The designers wished instead to provide an infrastructure that might activate latent forces on the site, including the need for artist displays or gallery spaces, shelters for the downtown lunch crowd, or smaller performance areas for buskers or street performers for whom the previous large-scale stage was over-scaled (the design features a smaller intimate performance venue on the roof of the stage canopy). The architects state:

The Cube functions as a multipurpose environment. The membrane ... [forms] a malleable and shimmering curtain that can stand like a wall, be pulled in to reveal the performance space, or function as a light-refracting surface - allowing it to morph into a projection screen, concert venue, shelter or sculptural object. When the stage is closed, the membrane's diamond extrusions capture and refract internal lighting or projections to their outer surface, creating a unique pixel matrix for artists to appropriate at will. (5468796 Website)
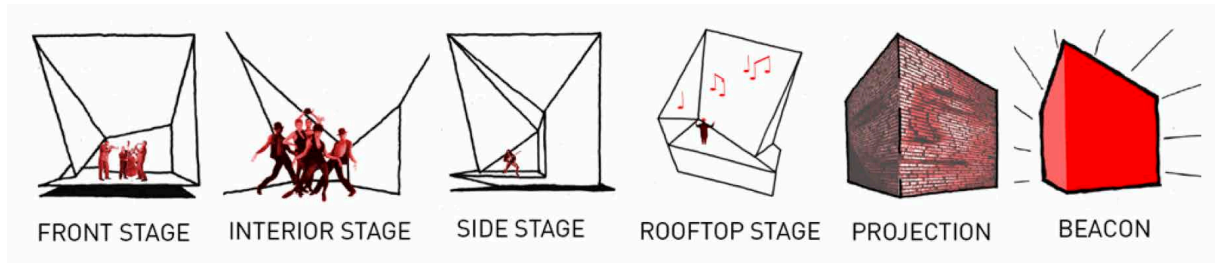

FIGURE 3.8 OMS Stage – Sample of Affordances

CAS PRINCIPLE:	OMS STAGE EVALUATION MATRIX:	
	LU Strategies	Observed Parallels with CAS
Adaptive and evolutionary	Create catalyzing environments that adapt to unknown futures	YES. The project can manifest in different states according to user needs. That said, the number of states is fixed.
Described by scale free / nested mathematical hierarchies.	Develop overlapping, interacting, organizational hierarchies	NO. There is no reference to hierarchies. However, it may be that the tendency for the stage to be appropriated in each of its modes may follow a power-law distribution.
Organized through flows and interactions	Leverage infrastructure and flows	YES. While the stage is built with many 'affordances', its particular manifestations of use are dependent upon the changing dynamics of the neighborhood.
Subject to non-linear & historical processes	Allow for non-linear, open-ended, & contingent transformations	YES. Currently, the upper level of the stage is seldom used and is generally unknown. However, over time, this 'possibility space' may be discovered and attract a large number of users. Use of the stage's modes may thus be path dependent, and subject to reinforcing feedback.
Characterized by self-organizing & emergent behaviors.	Foster process driven, emergent outcomes	YES. While the stage can be used in many ways, its most prominent usage will be an emergent feature.
Comprised of a diversity of agents	Activate bottom-up tactics & strategies to generate use	WEAKLY. The stage is a singular entity can manifest in eight different 'states'. In a sense, these states may be considered as competing agents vying for fitness.

TABLE 3.7 OMS Stage strategies related to CAS principles

§ 3.5   Discussion and Conclusion:

By omitting the material world from their theories (i.e., by treating it as contextual or epiphenomenal and thus causally irrelevant), planning theorists neglect the important role that things play in mediating the social interactions without which planning itself could not exist. (Beauregard, 2012, page 182)

Phillip Harrison describes the challenges of shifting from his work in academia to that of practice where, rather than theorizing complexity, he was required to act in complex settings. He notes: '*planning theory may have honed my conscience and improved my capacity to deliberate in a complex environment, but it did not provide me with guidance, or even an orientation, on substantive matters* (2013, page 68). The sample set of projects outlined above may be small, but they nonetheless each employ the rhetoric of CAS, while doing so through an engagement with the substantive object of planning. Here CAS engagement moves from being centered upon 'discourse' to instead being centered upon 'performance' (Lindholm, 2011, page 15).

We should, therefore, consider how well each scheme performs compared to its theoretical rhetoric. A comparison of the executed works shows how each engages with CAS in material contexts. We see from the comparative chart [Table 3.8], that each of the projects is able to meaningfully incorporate flows and interactions in ways that static, modernist plans have failed to do. Equally significant, four of the six projects, meaningfully incorporate self-organization and emergence within their scheme, or embrace adaptive and evolutionary outcomes. Two others deal with these aspects to a certain extent, but not as strongly. The most weakly articulated aspects of complexity pertain to how 'scale free' or 'nested hierarchies' are activated. A number of projects propose overlapping hierarchies in their concepts, but these remain weakly expressed in practice. The next weakest area is the notion of activation through bottom-up agents - only half the projects appear to successfully engage this aspect. While none of the built works fully address all key CAS dynamics, Almere (currently under development), comes closest to strongly meeting all of the CAS fundamentals. OMA's La Villette scheme is also strong in this regard, but remains a paper project.

CAS PRINCIPLE:	LANDSCAPE URBANISM FEATURE	Park de la Villette OMA	Park de la Villette Tschumi	Schouwbergplein (West 8)	Highline, NY Field Operations	Almere, Oosterwold MVRDV	OMS Stage, Winnipeg 5468796 Architecture
Adaptive and evolutionary	Create catalyzing environments that adapt to unknown futures	YES	YES	SOME WHAT	SOME WHAT	YES	YES
Described by scale free/nested mathematical hierarchies.	Develop overlapping, interacting, organizational hierarchies	SOME WHAT	SOME WHAT	SOME WHAT	NO	SOME WHAT	NO
Organized through flows and interactions	Leverage infrastructure and flows	YES	YES	YES	YES	YES	YES
Subject to non-linear & historical processes	Allow for non-linear, open-ended, & contingent transformations	YES	SOME WHAT	SOME WHAT	SOME WHAT	YES	YES
Characterized by self-organizing & emergent behaviors.	Foster process driven, emergent outcomes	YES	SOME WHAT	YES	WEAK	YES	YES
Comprised of a diversity of agents	Activate bottom-up tactics and strategies to generate use	YES	YES	WEAK	SOME WHAT	YES	WEAK

TABLE 3.8 Overall Project Comparisons

Table 3.8 suggests that there is still work to be done in successfully transforming discourse into practice, with the realized projects only partially succeeding in making their theoretical agenda operational. Accordingly, looking at the current state of Landscape Urbanism theory and practice, it is possible to highlight the components of CAS that are most strongly (versus more weakly) presently integrated into the discourse. **[Figure 3.9]**.
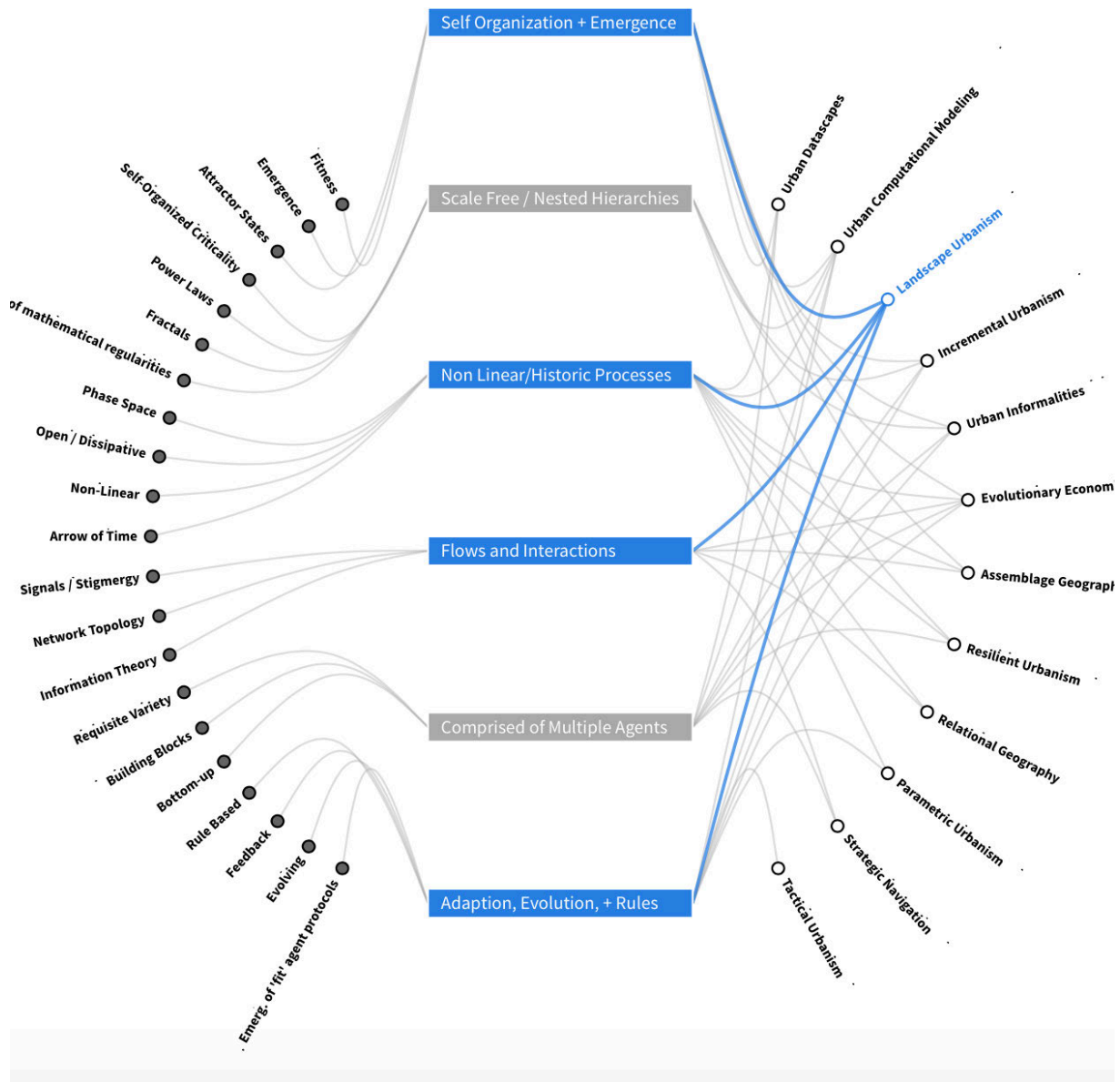
FIGURE 3.9 Strongest relations between CAS principles and Landscape Urbanism Projects
(the diagram, taken from the author's website (currently under construction), also indicates other discourses engaging CAS (see cas.seanwittmeyer.com)

While not fully fleshed out, the contribution of this built work to our understanding of built complexity is still significant. As a discipline, Landscape is primed to perceive the operational and temporal nature of its object of study - a living medium - as constantly in flux and evolving over the course of time. Landscape Architects can, therefore, more readily conceptualize how to be stewards of shifting

realities. Landscape is thus, 'a medium uniquely suited to the open-endedness, indeterminacy, and change demanded by contemporary urban conditions' (Waldheim, 2002, page 13).

I further wish to suggest that the manner in which Landscape Urbanists think about designing the *open spaces* of the city has important clues to offer those interested in the planning and design of the *built fabric* of the city. Landscape Urbanism's acceptance, appreciation, and stewarding of shifting realities begins to provide insights as to how we might wish to orient ourselves if we truly want to build cities open to Complexity. The techniques that LU advocates - creating flexible spatial affordances by drawing together different forms of flows to an enabling territory – could equally apply to the built features of urban fabric. Instead of seeking to stabilize urban form, this would involve creating a framework of flexible and responsive urban fabric that allows urban flows - resources, information, materials - to become meaningfully grounded. Here, we would be tasked with considering how planning might generate responsive form that frames and stages multiple actions, without predetermining these. This form might be conceived as a 'mutable immobile … allowing certain behaviours and prohibiting others' (Heynen, 2013, page 353)

This then begs the question: if cities are complex environments, then how do we 'build in' more mutability to respond to a greater breadth of situated possibilities? The example of the OMS stage – a highly mutable environment that can be appropriated in distinct ways - begins to suggest the kind of 'enabling site' required for this to occur. The creation of multiple enabling sites within the territory of the city would permit different kinds of programs to find their best 'niche' in accordance with shifting realities, responding to flux and evolving relationships.

Finally, this article would be incomplete without a nod to work being advanced by assemblage geographers. There are a number of conceptual threads within this work that link it to this body of work. Assemblage geographers have also called attention to the specifics of material things while emphasizing that these must retain both their *virtual* capacities as well as those that are *actualized*. Further, Assemblage and CAS are also acknowledged as interwoven discourses, where 'complexity theory provides a conceptual language for understanding how assemblages work over time' (Dittmer, 2014, page 391). I believe that the work of assemblage geographers is important, but also note that is has been criticized for using modes of analysis that remain opaque (Robbins and Marks, 2010). This has rendered the value of this contribution somewhat less accessible to practitioners and those outside a very specialized discourse.

By providing documentation of real-world, situated projects, using a systematic method of analysis that employs highly structured matrices, I have thus deliberately attempted to 'pin down' a subject that often seems to float away due to its mutable nature. The projects above serve to illustrate how, while remaining open to contingent possibilities, it is possible to nonetheless imagine, instigate and activate forms of 'grounded specificities' that come to be actualized in specific circumstances (Woodward et al., 2010, page 276). The contribution thus seeks to provide a more concrete understanding of the nature of such material conditions: ones that support the unfolding of Complex Adaptive Urban processes.

4 Tactical Urbanism as a means of testing relational processes in space: A Complex Systems Perspective.

Abstract

Too often, master planning strategies have failed to produce spaces responding to the social, cultural and economic needs of their inhabitants. Accordingly, many planners have turned to relational strategies to redefine their practices. These tend towards methodologies that explore relational forces *preceding* design interventions rather than unfolding *by means of* design interventions. This paper considers an alternative mode of understanding relational processes: one that considers tactical urban strategies theorized through the lens of complexity theory. The paper argues that tactical approaches harness relational junctures *in situ*, effectively exploring relational configurations of cohesive urban environments. A design competition entry provides an illustrative example of this approach: one that channels and choreographs relational urban processes.

Introduction

Traditional planning strategies, situated within Modernist paradigms, sought to resolve urban problems through methods of instrumental rationality. These assumed problem spaces to be bounded, involving linear processes that could be understood and controlled using an engineering mindset to streamline and optimize processes. Here, *'city planners and the plans they produced assumed that cities were in equilibrium and the focus was almost entirely on implementing some form of blueprint depicting a desired end state'* (Batty and Marshall, 2009, page 563). Accordingly, to plan effectively meant to 'map' - with the blueprint considered a neutral and objective platform that steered action – rather than a power-laden construct that risked reproducing situations of inequity (Healey, 2007).

The failure of these blueprints to achieve desired outcomes, combined with a general shift away from modernist ideology, has moved planning towards more contingent, reflective, and critical stances. These recognize the need to move beyond a faith in master-plans with their end-states, and instead

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acknowledge unknown, ambiguous futures that are often fragmented, relational and complex (Boonstra and Boelens, 2011). Here, environments are conceived not as a static entities situated within containerized Euclidean space and time, but as evolving constructs - constantly produced and reproduced by various actants, holding multiple perspectives (Anderson et al., 2012; Graham and Healey, 1999).

This orientation, focusing upon processes, actors, and the dynamics that generate urban form, has been framed as the 'relational turn'. This turn steers planning away from traditional modes of practice – that privileged physical interventions in the urban setting - to instead focus upon understanding and influencing the *procedural* aspects of change. This implies a new emphasis on identifying flows and strategic convergences that may be stimulated and reinforced to achieve planning objectives, while acknowledging the influence of both human (and non-human) actors. Patsy Healey describes how in this perspective,

...the work of strategy formation becomes an effort to create a nodal force in the ongoing flow of relational complexity. This force is drawn forward through the effort of 'summoning up' conceptions of an urban area, in ways that selectively lock together some transecting relations, opening up connectivities to encourage new synergies to emerge, creating a strategy with persuasive and seductive power, that can become itself an 'actor' in the ongoing flow of relational dynamics and have affects on materialities and identities. This implies that planning efforts have to abandon the idea that there exist some pre-given spatial ordering principles that can provide a legitimate basis for interventions in the emergent realities of urban areas. (2007, page 228)

Unfortunately, this abandonment of 'pre-given' spatial ordering principles, generates a rift between those theorizing about cities, and those generating designs within cities. In order to address this gap, this paper considers how relational perspectives might inform design processes that unfold *within* urban space.

I come to this research as a North American, practice-based, urban designer. Within this context, planning theory is dominated by denunciations of urban sprawl coupled with advocacy for 'smart growth' cities that reclaim a sense of place and vitality (spearheaded in large part by New Urbanists (Grant, 2009)). Here, practitioners focus upon methods of achieving 'good' urban form as it manifests *on the ground* (the morphological aspect of urban space), and much less-so with understanding and restructuring the relational forces that underpin form (Gunder, 2011; Moore, 2013; Veninga, 2004). Given the specificities of this context, while remaining intrigued with how relational thinking can inform space-making, my primary concern is with how this affects routines of situated practice - particularly the execution of urban design interventions.

This notion of 'intervention' in planning can be framed in two ways. The first concerns intervening within the planning processes itself - who is involved, what are the planning tools, how are power imbalances recalibrated: in short - the manner through which plans are *conceptualized*. The second concerns how specific interventions at the physical level are *actualized*: how specific built forms are produced in space, and how these interventions - as physical entities - then change the nature of space and relations on the ground. Whereas planning used to be dominated by the latter (the generation of master plans), it has come to be dominated by the former. This rupture between the *process* versus the *substance* of planning has meant that, while relational planning considers a '*variety of complex and reciprocal relations and exchanges*' that underpin planning processes, including '*money, power, gender, ethnicity*', it has nonetheless abandoned '*the contemplation of space in any other manner, such as in terms of proportion, pattern, extension, or the spaces between things – in effect, principles that can be used to generate spatial arrangements*' (Milroy, 2010, page 24).

In order to help redress this imbalance, this pa-suggests a consideration of *tactical approaches* that may have the capacity to side-step the pitfalls of traditional master planning strategies while nonetheless remaining engaged in the specificities of form, site, program and spatial arrangements in urban settings. The recent pedestrianization of Times Square in New York, is a case in point, demonstrating how a significant shift in design and programming can occur by virtue of tactical approaches – in this case banning cars and instead positioned 376 lawn-chairs (at $15 apiece) in the space. Those opposed to pedestrianizing the intersection had anticipated increased gridlock in the surrounding area, with business owners worrying that a traffic ban would cause a downturn in revenues. Rather than argue the point, the city simply experimented: gathering data that showed the intervention, *'led to less congestion, shorter travel times, less accidents, more pedestrians, and eventually upped Times Square into the top 10 of world's most valuable retail destinations'* (Hämäläinen, 2015).

While such tactical strategies are beginning to be documented and discussed they are, for the most part, presented as examples of grassroots resistance or community empowerment (Lydon and Garcia, 2015). I wish to shift the focus of the discussion to instead highlight how tactical strategies also resonate with relational approaches, but in ways that move from *understanding* relational forces, towards a*ctivating* relational forces. As the New York case illustrates, meaningful consensus surrounding change (where scepticism was initially high) might occur through direct stakeholder *experience* of consequences rather than through discussion, planning, and debate.

Finally, I wish to consider how tactical strategies might shed new light upon Complex Adaptive System (CAS) approaches of engaging urban issues. Though CAS has entered into planning discussions in various forms – some computational, some procedural, and some theoretical – there is a dearth of research into CAS processes as something that can be operationalized 'on the ground'. I wish to demonstrate how tactical strategies might be theorized both as advancing a relational spatial ontology, and as exhibiting CAS attributes. This contributes to planning scholarship by fleshing out conceptual links between CAS and tactical approaches that, to date, have remained largely under-theorized (for exceptions see Silva 2016; McFarlane 2011).

Section One of the paper situates this research within the background of relational planning perspectives. While not intended to provide a comprehensive critical review (which has been undertaken by others - see: Jacobs 2011; Yeung 2005; Graham & Healey 1999), this serves as a backdrop for the ensuing discussion of tactical practices. Section Two introduces tactical approaches, discussing the principles of tactical engagement and providing a series of generic examples. Section Three moves to a more specific illustrative example, which conceptualizes how urban tactics might be positioned as a means of engaging relational forces *in situ*. Section Four then outlines how this project can be read as a Complex Adaptive System, and how this reading corresponds with a relational approach. I conclude with reflections on both the limitations and contributions of this work.

§ 4.1 **Part 1: Relational Planning Perpsectives - modes of discourse and story-telling**

Relational thinking can be seen as an attempt to engage uncertain futures, addressing the fact that envisaged planning scenarios are likely to change by the time plans are implemented. This alternative mode of planning - one that provides more provisional and flexible strategies to manage uncertain

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and evolving situations - is seen as a corrective measure to the failure of master plans to achieve their specific end states (Balducci et al., 2011).

While relational strategies differ in emphasis, they are united in shifting the emphasis of planning away from the *object* of planning itself (the physical urban environment), so as to instead attune to the *processes and relations* that fuse in planning contexts. (Amin and Thrift, 2002; Massey, 1999; Urry, 2003). This turn from form to process, leads relational planners to draw from conceptual sources that have the capacity to inform a process driven ontology. These sources include Complex Adaptive Systems (CAS) theory, with its emphasis on bottom-up processes that lead to emergence (Holland 1996; Batty 2007); post–structuralism with its 'planes of immanence' that capture potential relations through contingent assemblages (DeLanda, 2005; Hillier, 2008); and communicative theories that emphasize the agency of various human and non-human actants (Innes & Booher 1999; Healey 2007). While these sources differ, all engage with *'open-ended processes and dynamics rather than static normative forms'* (Graham and Healey, 1999, page 625) Healey and Graham effectively encapsulate the major themes of these perspectives, summarized as:

— Relational vs absolute theories of time and space (where multiple times and spaces may coexist);
— Multiple meanings and social realities that construct superimposed spatial realities (as opposed to one 'objective' social reality);
— Networked geographies that imply stretched and compressed geographies, constructed according to infrastructural and performative hierarchies;
— Power as a significant factor in social agency that produces social/spatial realities – with power playing a strong role in determining which spatial practices are privileged.

There is a great deal of overlap between these themes, with boundaries blurred as practitioners interweave the concepts to differing degrees. What is common is that the planning process - with its previous emphasis on proscribed futures and physical components - is reconceived in relational, contingent and non-linear terms. As part of this reconceptualization, the focus of planning shifts towards an emphasis on the social, political, procedural and power-laden agencies that steer plan decision-making. Once extended into the domain of practice, this becomes instituted in methods that gravitate towards discursive modes – with an emphasis upon acts of dialogue, participation, rehearsal, and storytelling.

This tendency towards discursive modes can be examined through the consideration of a number of influential planning streams, including communicative strategies, post-structural methods, and computational approaches (which I tentatively situate as a form of narrative). These streams can, respectively, can be characterized by the figures of Patsy Healey, Jean Hillier and Mike Batty. While others could easily have been named, I will focus upon the contribution of these individuals not only because each are acknowledged as having exerted a considerable influence within their respective discourses (which range from the *'computational to the baroque'* (see de Roo et al. 2012, p.41)), but also because each engage aspects from complexity sciences within their work - albeit in different ways. That said, I wish to argue that ultimately the approaches they represent lead towards speculative discourses rather than physical interventions.

§ 4.1.1 Communicative Strategies – Patsy Healey

For Healey, 'the plan' is but an outcome of the planning process, which itself results from a network of complex interactions. Healey thereby champions communicative approaches that permit diverse voices to be engaged and understood – ensuring a more inclusive means of generating dialogue that can thereby offer a fuller understanding of the complex forces underpinning plan-making (Healey, 2003). Here, planning refocuses itself around decision-making processes and the power of multiple, inclusive, voices: engaging more players and drawing upon 'bottom up', 'insider' perspectives, rather than relying upon 'top down', 'expert', and outsider perspectives. Rather than making plans, the planner is charged with unpacking the communicative processes and governance models that control plan-making. Susan Fainstein, reflecting upon relational trends within planning observes:

Within communicative theory the planner's primary function is to listen to people's stories and assist in forging a consensus among differing viewpoints. Rather than providing technocratic leadership, the planner is an experiential learner, at most providing information to participants but primarily being sensitive to points of convergence. (Fainstein, 2000)

This planning mode focuses upon emergent properties, contingent outcomes, and open-ended processes - hence Healey's employment of the term 'complexity'. Cities are understood as '*complex performative arenas, where relational webs weave layers of order between heterogeneous social groups, filières of firms, governance agencies, etc.*' (Graham and Healey, 1999). The planner's role is to structurally intervene within this web of relations, ensuring fair discourse, whilst remaining cognizant that the normative notions of 'desirable' end states are contestable. '*Assessing whether, when, where and how to intervene in these relations in an attempt to make a significant difference to trajectories and outcomes is, in turn, a complex political task*' (Healey, 2007, page 186).

Healey aims to navigate this complex realm of social dimensions, as opposed to the built complexity of the physically manifested city. It follows that analysing the city is essentially a discursive task, concerned with unpacking the social and political aspects of plan-making, compared to a traditional 'taking stock' of the physical components of urban form and character. The planner's role thereby shifts from that of expert advisor on morphological aspects of the city, to that of mediator working to foster just and inclusive dialogue regarding the city (Healey, 2003, page 108). The resulting *conversation* then becomes the means used to legitimize any ensuing planning action. That said, while Healey argues that the planner's role is to intervene in 'guiding trajectories', she stops short of developing tools that would inform acts of intervention themselves.

§ 4.1.2 Post-Structural Methods – Jean Hillier

A second perspective on the integration of relational thinking into planning practice can be represented by Jean Hillier's work. Hillier considers how post-structuralism provides planners with a conceptual umbrella for relational planning, '*concerned with structuring processes and the undecidable relations or connections between structures and agencies*' (Balducci et al., 2011, page 487). Like Healey, Hillier is interested in planning process situated within relational contexts, but she focuses on the non-linear, uncertain and contingent aspects of this relational space. In contrast to communicative approaches, Hillier eschews binary distinctions between actors, instead employing shifting and contingent *differentials*. Further, discussions are framed more around *potentialities* (or

'the virtual') rather than specific, stabilized relations: 'foresighting' more than 'forecasting' (Hillier, 2011; Sheppard, 2008). Here the focus shifts to speculations regarding multiple trajectories of becoming, tracing how trajectories interact to form temporary, stabilized relations.

Hillier considers environments from a complexity perspective, regarding them as, *'assemblies of a multiplicity of heterogeneous components, in which heterogeneity or difference plays a crucial productive role in the driving of fluxes.'* (Hillier, 2005, page 276). Space accordingly, is *'a multiplicity which brings together characteristics of externality, simultaneity, contiguity or juxtaposition'* (Hillier, 2005, page 282). The philosophies of Deleuze and Guattari, and in particular their notion of *assemblage*,[15] are then adopted as a means to speak of this multiplicity, characterized by wholes that are provisional, contingent, and relational, that come into being and dissolve in accordance with the energies and fluxes they are subject to: *'these assemblages are never fixed or stable, but always in a process of making or unmaking. Such instability (mobility) means that there is always potential for innovation, an eventful differentiation. As such, it is also assumed that assemblages have distributed agency* (Jacobs, 2011, page 416). To comprehend this agency and its generative potential, Hillier relies upon cartographic processes outlined by Deleuze and Guattari. These cartographies 'map connections' and illustrate 'relations and forces'. Accordingly,

...one may be able to anticipate the potential power of force relations between the various actants and what they might become capable of achieving. Cartography as a process would request strategic planners to diagram and engage the interconnections between elements, to experiment with them and anticipate potential tensions and conflicts. What new assemblages might eventuate? What strategic agencements? (Hillier, 2011, page 515)

In this reading, 'mappings' are largely metaphoric, as they trace socio-political forces that remain largely invisible, rather than relations and forces that are *physical* in nature.

Within this political/spatial context, the planner's role is to *trace* the relevant actors at play, *anticipate* the significance of various relations amongst these actors, and finally *intervene* at appropriate system leverage points in order to successfully steer potential trajectories (Hillier, 2011, page 516). But in practice 'mappings' are outlined primarily through discourse, where scenarios are debated and futures are 'rehearsed' in ways that draw attention to particular relations and benefits (Hillier, 2008). Accordingly, the post-structural planner's task, according to Torill Nyseth, is primarily to: *'stage the discourse'; 'open minds up to new ideas'; 'give voice to new actors';* explore *'methods of active invitation';* and engage *'diverse sets of views'* (2011, pages 581–88). Through such discourses Hillier's meshworks are enriched as the dynamics between, *'the withs and withouts', 'power plays' and 'insurgencies'* (2005, page 288) are unpacked. She states, *'these tracings then become part of the map'* (2011, page 513).

I wish to emphasize that this 'mapping' engages the complexity of the social, rather than the complexity of the (physically) spatial. Jeff Malpas notes this conceptual slippage in spatial geography, arguing that it blurs the lines between physical and discursive spaces. He cautions that, *'few thinkers, no matter what the discipline, have given serious attention to the phenomenon of space... [they] have tended instead to deal with various forms or modes of space – to spatialities rather than to space as*

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15   This notion of Assemblage is roughly equivalent to the concept of Emergence in complexity adaptive system theory (see Anderson & Mcfarlane 2011; Sheppard 2008). Even the phrase 'complex adaptive assemblage' has been proposed (Dovey, 2012).

such.' (Malpas, 2012, page 226). He considers geographer Doreen Massey's views as representative of this stance since,

…what interests Massey is less the understanding of space than the social or political consequences of any such understanding. One might thus argue that what Massey offers is not a more adequate theorization of space, but instead a theorization of spatial rhetoric and of spatial imagining as this forms the core of a spatial politics. (Malpas, 2012, page 228)

Overall, post-structuralists tend to maintain a focus on mapping *socio/political* assemblages - motives, histories, actors and cross sections of power – that serve as the backdrop for plan decision-making. At the same time they refrain from the mapping of *morphological* assemblages - buildings, landmarks, streets, or bridges – that situate planning in physical space. This centers the role of planning in modes that work to define the design problem (through discursive tracings) rather than implement the design solution (through spatial interventions)

Interestingly, Deleuze and Guattari's mappings might equally be employed to trace physical artefacts – ones situated within the concrete phenomena of the city (as Manuel DeLanda (2000) has demonstrated). Notwithstanding this potential, in instances where post-structuralists explicitly consider material artefacts, they do so in ways that equivocate *all* material aspects - such that the agentic materiality of a railway ticket is no less significant than that of a public square (McFarlane, 2011b). While conceptually this perspective is in keeping with a non-linear ontology, in which seemingly minute details may be implicated in activating broad outcomes – the so-called 'butterfly effect' - the resultant 'flattening' of all urban aspects has been criticized as making it near impossible to prioritize action (see Storper & Scott 2016, p.23).

Accordingly, Hillier offers limited guidance on conducting any form of physical intervention, suggesting only that planners shift their focus away from prescriptive plans and towards performative outcomes (Hillier, 2008). She advises that planners examine, '*via detailed interventions, how different innovations may perform in different spatio-temporal circumstances'* (Hillier, 2008). She remains, however, non-specific as to the means with which to execute these 'detailed interventions', saying only that this calls for '*creative, nonconformist ways of thinking and working, proceeding by intersections, crossings of lines, encounters'* (Hillier, 2005, page 284). We will return to this thought later.

§ 4.1.3   Computational Approaches – Mike Batty

Turning to a very different planning perspective, Mike Batty has been at the forefront of investigating how cities can be conceived as complex systems, with their dynamics unpacked through the use of computer simulations. He has spent decades developing agent-based and cellular automata models that can also be viewed as a means with which to engage a relational ontology. Here, Batty (as representative of computational modellers in general) explores potential urban trajectories and possible futures (Manson and Sullivan, 2006). The models are adjusted through testing interaction rules amongst agents in the model (within a certain range of limits), adjusting input parameters (services costs, real-estate costs, population incomes, etc.), and surveying the outcomes of these various parameter sets. These simulations offer glimpses of 'possible futures' that may also predict particularly stable outcomes that remain robust in the face of shifting rule or parameter sets. This may also suggest plausible leverage points that push an urban system towards a particular (favoured) and potentially robust trajectory.

That said, these trajectories, due to the non-linear forces at play, cannot be controlled with any degree certainty. While the models may provide insights into the dynamics of how various decisions or actions play out, their predictive power remains limited. This, in part, is due to inherent constraints on the modeller's ability to faithfully calibrate model dynamics, as well as limits regarding what the model does or does not include. Often, datasets are incorporated simply because of their availability, rather than because they are representative of the most salient factors. Further, even if all relevant datasets were to be available, other problems ensue. As models became more complex to account for more variables, '*data requirements exploded to the point where it became impossible to even calibrate, never mind validate, such models*' (Batty, 2009, page 53). Discussing these inherent limits, Batty and Torrens state that, ultimately '*such models are pedagogic... demonstrations of what is possible, and in the last analysis, provide vehicles for discussion... for argumentative discourse.*' (2005, p.763)

Were it possible to calibrate the models, we would still be left with determining (in a deliberative manner) which goals or parameters to prioritize (by assigning with computational 'weight'). Models allow different potential futures to play out, but the selection of which future we wish to try and enact remains dependent upon decision-making processes wherein we gauge *which potential story is most desirable*. Batty and Torrens therefore observe that selecting interaction rules mirrors 'decision-making' processes in policy-making environments, and that a meaningful modelling of one may be predicated upon a modelling of the other (2005, page 763).

Accordingly, Batty has begun to explore how computational models might be used to explore the dynamics surrounding decision-making 'trade-offs' in planning consultation environments (Batty, 2013). This work, while in its nascent state, shifts perspectives from modelling physical environments to modelling their associated decision-making contexts. It thus echoes the kinds of communicative and post-structural processes outlined above. Hence, whereas Hillier speaks of a kind of 'mapping' that would trace power agencies within a planning context, Batty interprets this as assigning algorithmic rules to these interactions, translating the map into a simulation that can be re-programmed and refined. Hillier describes how,

... the political practice of spatial planning [is to] to 'test out', via detailed interventions, how different innovations may perform in different spatio-temporal circumstances. The complex interplay of factors at any specific conjuncture nevertheless means that successful intervention cannot be guaranteed. There are always too many unknowns to give certainty. [but].... they offer an opportunity for creatively experimenting with a range of different articulations of these issues. (Hillier, 2008)

Her statement might equally be attributed to Batty, whose work involves a 'testing-out' - via computer models steered by algorithmic rules - of various scenarios, paying attention to how different circumstances and different 'computational weights' of these might affect outcomes. Like Hillier, Batty acknowledges the practical limits of this approach given the endless number of factors that might influence a particular model. However, his models, like Hillier's mappings, '*offer an opportunity for creatively experimenting with a range of different articulations of these issues*' (Ibid, p.34)

Despite a very different starting point then that taken by Healey and Hillier, I suggest that Batty's computational work ultimately moves strikingly close to one that centres upon providing tools to facilitate discourse. Here, as Batty himself acknowledges, models are useful, '*as much for their exploratory and discursive value in a wider participatory process of developing robust but contingent knowledge than for their ability to generate good theory*' (2009, page 56). In contemplating *The Limits to Prediction,* Batty and Torrens therefore suggest that a 'particularly useful' application of models is that of 'story telling' used to '*structure discussion and debate*' generating ''*what if?' scenarios*' (2005, page 762).

Ultimately, while the 'front end' work of modelling engages bottom-up and complex interactions to produce stories and provide insights for planning or thinking about interventions, the physical enactment of interventions 'on the ground' remains ambiguous, and likely top-down. Models may provide stories of potential futures, but the planner is still left with the task of operationally intervening – within a context that is physically situated – to steer some of these stories into fruition. At the point when physical intervention becomes necessary, it is unclear what tools are to be employed, and how these differ in nature from those instrumentalized within top-down plans. Further, there is no way to reliably predict the level of correspondence between policy 'rules' in the model and the actual effects of policy implementation 'on the ground'.

§ 4.2   **Part 2: An Introduction to Tactical Strategies**

The perspectives outlined above point to a significant gap between modes that stage the planning problem, and mechanisms used to implement the planning solution: between 'rhetoric and action' (Fainstein, 2000, page 460). To summarize, all the approaches above consider cities to be complex systems of interactions in which prediction is almost impossible. Nonetheless, in each case planners focus upon rehearsing, outlining, or modelling scenarios surrounding potential trajectories. Little specific guidance is provided into how one might then move on from understanding the problem space to enacting the problem solution. Here policy decisions would seem to be the right instrument, but while policy decisions may help steer development trajectories, they too are subject to unintended consequences, where the desired trajectory is disrupted despite all the best efforts at 'forecasting'.

These unintended consequences are part of the problem of 'solving' problems within complex environments. If cities are complex, then seeking to exert control over outcomes may well be antithetical to their fundamental nature. Interventions - however well intentioned - are derived from attempts to understand potential scenarios, actants or simulations, but cannot address the basic uncertainty of relational contexts. The next part of the paper therefore proposes to set relational *forecasts* aside and instead examine the potential of relational *enactments*. Before clarifying this distinction, I wish to offer the following snapshots of strategic interventions that may help ground the ensuing discussion:

… for two weeks in 2012, 41 pianos in Toronto, Ontario were modified by 41 artists and distributed within the city. Each piano bears the invitation, 'Play me, I'm yours'. The instruments' respective locations became sites of impromptu concerts, sing-a-longs and discussions;[16]

… for three weeks in the summer of 2012, 'Pop Rocks' transformed one block of downtown Vancouver into an informal lounge. Robson Street was closed to traffic and instead occupied by a series of enormous bean bag chairs, protected by umbrellas that invited citizens to 'socialize, rest, eat, or read a book in the heart of downtown' (Vancouver, 2012); and

… in 2012, 'Popuphood' in Oakland, California, began to transform vacant storefronts into vibrant businesses. The small business incubation project provided free initial leases for start-ups, thereby

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16   Concept developed by Luke Jerram.

lowering their risks of entering the marketplace. Organizers concentrated these enterprises onto one specific block, creating a sustained flow of clientele and promoting synergies between stores. Following the initial pilot period, successful enterprises transitioned to permanent status with long-term leases, thereby promoting 'visibility, vibrancy, and safety, block by block' (Popuphood website).

The above provides a sampling of what has been dubbed 'tactical urbanism' (Lydon and Garcia, 2015). Here, transformation of an urban site is provisionally tested prior to committing to large-scale investment, but if successful, these interventions can ossify into permanent projects. While the specifics of tactical projects differ, their execution strategies are similarly orientated in that they: *create juxtapositions* (by developing novel spatial connections that draw together a variety of actants); *probe lightly* (by undertaking low risk investment explorations prior to committing to permanent actions); and *explore widely* (by pursuing multiple spatial potentials quickly and nimbly).

The next section illustrates how such tactics might provide an alternative manner whereby planners might engage relational processes. Here, instead of working to trace, simulate, or unravel the complexity of cities, planners would instead create *the circumstances whereby city designs might emerge directly* through the harnessing of complex adaptive processes.

§ 4.3   **Part 3: City Crossing Competition - steering complex processes in situ**

The task of city planning has become less one of producing the simple order of 'rational' urban plans, but one of how best to generate and maintain the functional complexity – or complex functionality – traditionally possessed by cities…The somewhat paradoxical challenge of planning then becomes one of how to 'plan' a kind of complexity that seems to have arisen 'naturally' in traditional cities, without planning. (Marshall, 2012, page 192)

What follows is a discussion of a competition submission that engages Tactical Urbanism and Complexity thinking in a deliberative manner. The submission was prepared by an urban design and architectural practice of which I was a member.[17] The work provides a 'thought experiment' illustrating how one might physically intervene within an urban setting, while nonetheless remaining open and responsive to contingent, complex, and relational urban forces. Rather than a plan, the project posits a *process* that gradually unfolds, leading towards more 'fit' outcomes. It can be read as operationalizing Hillier's call, (referenced earlier), for *creative, nonconformist ways of thinking and working, proceeding by intersections, crossings of lines, encounters'*. What follows outlines the scope of the project, after which the work is positioned in relation to complexity theory.

In 2004 the City of Winnipeg in Canada launched an ideas competition to revitalize the Portage and Main intersection (the junction of the city's major traffic arteries) that for years has been closed to pedestrians in order to facilitate vehicular movement. The original closure resulted in storefronts shifting underground, exacerbating urban conditions that were already leading to desolate streetscapes both at the intersection and in the surrounding neighbourhood. The competition brief

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17   Cohlmeyer Architects, Winnipeg, Manitoba, Canada.

emphasized that the project was intended to instigate revitalization beyond the confines of the site, the surrounding area being characterized by surface parking lots and a surplus of empty storefronts.

It was evident that the competition organizers were seeking a 'signature' project to be inserted at the intersection. Our team, however, believed that problems of the intersection were the result of systemic issues distributed across the downtown as a whole, and that any intervention merely targeting the intersection itself was doomed to failure. We considered the site as a significant node within a relational network and felt that failures of the node could only be addressed by dealing with the network in its entirety – in particular the fact that there were insufficient resources activating this node.

Our urban analysis aimed to identify and map territories of untapped relational potential, including urban sites that, despite being located in the city's core, were vacant or underutilized. The competition site was framed as being but one amongst many undervalued and under-programmed areas that might be reclaimed through an alternative conception of the city. This led our group to map seven classes of underutilized urban terrains, catalogued as: *rooftops to inhabit, walls to scale, streets to claim, plazas to program, surfaces to alter, businesses to infest, and lanes to liven*. The list was intended to evoke different forms of urban potential, without pre-determining any particular site as a targeted area. In this sense, the list is both generic and specific, offering a classification of morphologically distinct urban spaces, without pre-determining how each might be used.

A similar exercise was undertaken to catalogue different kinds of urban programs. Given uncertain futures, designating specific programs – such as 'hair salon here', 'housing there' - was seen as counter-productive. Instead, a catalogue of seven programmatic 'classes' was identified, aiming to capture the diversity of urban actions. These were (provocatively) labelled as: *urban play, urban voyeur, urban voice, urban cheap, urban trade, urban sin, and urban extreme*. Again, the classes were somewhat generic in that 'urban voice' might manifest in a variety of forms: a billboard, a speaker's box, or an open-air concert, for example. Notwithstanding, the category of 'voice' is specific in that it connotes the role of the city as place that fosters dialogue (arguably a mode through which conviviality is achieved). The urban program classifications were thus not intended to be literal, but instead serve as a kind of provocative catalogue: one used to instigate discussion regarding different kinds of actions or programs that promote civic vitality, while remaining open to the ways these might be actualized.

We then turned to consider medieval town precedents: spaces that evolved incrementally over centuries through trial and error, gradually yielding urban structure tuned to the needs of occupants (Alexander, 1979; Rudofsky, 1987). We felt these precedents offered clues for understanding how evolutionary processes might permit appropriate civic form to be 'self–generated' out of competing interests. We nonetheless recognized that, given today's rapid pace of development, the ability to test ideas incrementally would need to be re-conceived.

In the absence of long time periods that would permit *successive* generations of spatial iterations (each learning from the last), we therefore created a mechanism to activate a multitude of *parallel* spatial iterations, accelerating the speed by which the urban network might 'learn'. We introduced *'seven days of the week'* as an *iteration generator* that would cycle through civic permutations. Over the course of a year we assumed 356 parallel 'probes' of urban potential. Each of these might be of differing duration and magnitude, but a broad variety of probes would be insured.

Our proposal thus assembled three kinds of forces interacting in a relational manner– contingent *times*, contingent *programs,* and contingent *sites* - brought together in various permutations and combinations. The 7 x 7 x 7 matrix [Figure 4.1] of space, time, and action formed the conceptual

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underpinnings of this relational schema, one that could explore potential spatial trajectories. The matrix behaves as a kind of permutation or assemblage generator: prompting explorations of novel ways in which to explore the latent potentiality of various sites and thereby determine which sites, programs, and times might be most productive.
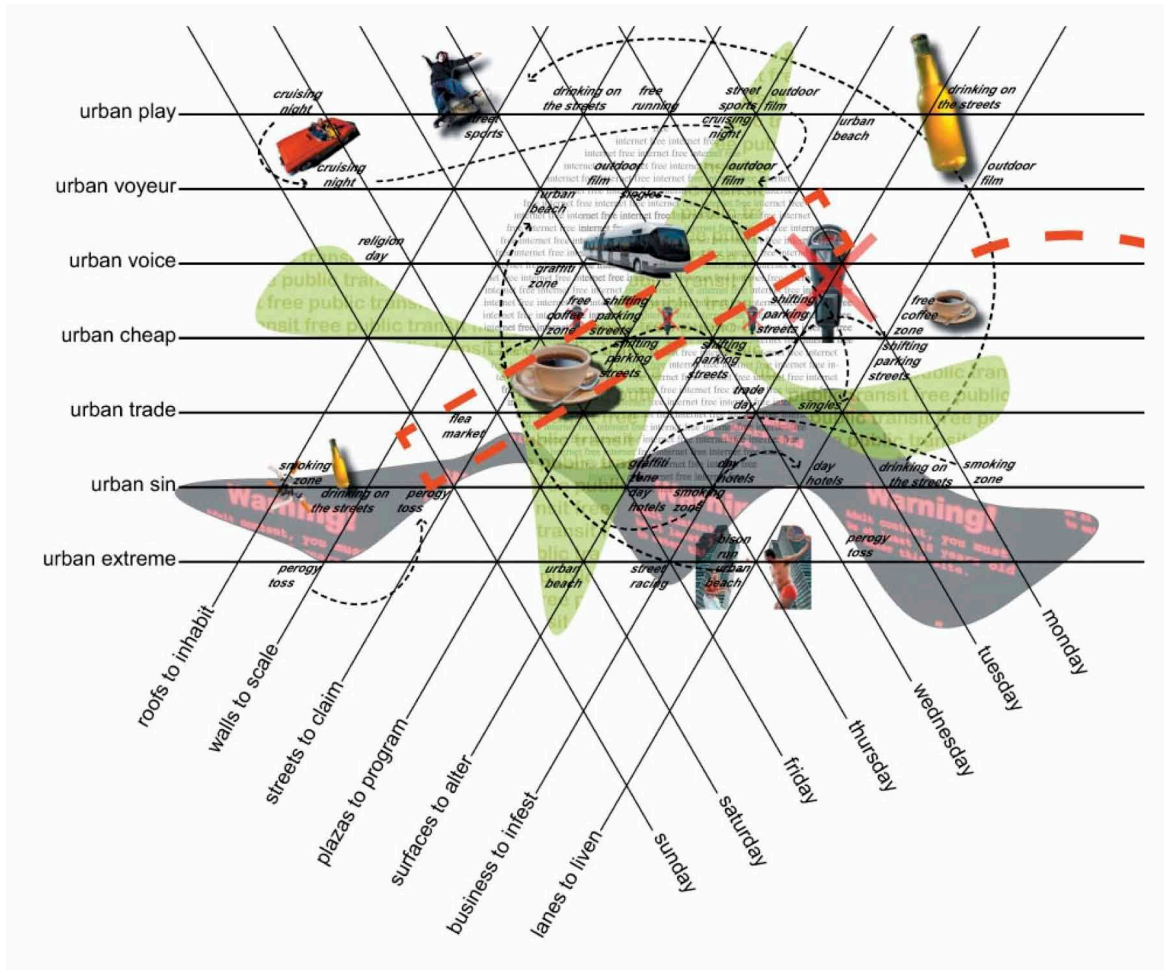
FIGURE 4.1 7 x 7 x 7 matrix or relational possibilities (Image credit: Cohlmeyer Architecture Ltd):

Rather than presenting fixed relations, the matrix is intended to evoke of the *kinds* of acts that might occur as temporal, spatial, and programmatic contexts intertwine in unexpected configurations. Solid lines highlight the potentiality of particular programs manifesting on particular days and on particular sites. Dashed lines suggest the migration of programs to different locations. Shaded amorphous areas suggest catalytic relations emerging amongst different sites and programs. The ambiguity of the map is intentional, corresponding with the ambiguity of the terrain being mapped. Here, the matrix might be read as a kind of operative analogue to the kinds of tracings that Hillier refers to when speaking of forecasting scenarios, a *'plane of consistency [where] all possible events are brought together and new connections are made and unmade continuously'* (Hillier, 2008). Accordingly, it is not the relations themselves that matter, but rather the processes whereby specific relations assemble into emergent wholes.

In order to operationalize the diagram, intersections are contemplated, prompting discussion of what 'happening' might manifest in a given instance. For example, the act of 'urban play' might be activated on the territory of 'streets to claim' and tested at a moment in time - a Sunday in May. The nature of play, its particular site, and the moment during which this iteration is activated are not specified, but the diagram begins to suggest unexpected options. What might one use a roof for on a Tuesday in November? What street might perform as an urban beach on a Saturday in July, or be appropriated as a cross-country ski route on Sundays in December? The selection of which interaction to enact would not need to be deliberated upon at length but could simply be enacted at random in response to the 'what if' prompts of the matrix itself. In this way, unexpected trajectories would be set in motion leading to new, unexpected outcomes.

The 7 x 7 x 7 matrix thereby resonates with an assemblage perspective in geography where, *'urban actors, forms or processes are defined less by a pre-given property and more by the assemblages they enter and reconstitute',* and where emphasis is placed upon, *'the depth and potentiality of urban sites, processes and actors'* (McFarlane, 2011a, page 209). Here, agency is extended to consider the material properties and capacities of particular settings, and we become interested in the framing of 'potentialities'. This refers,

...both to the intensity and excessiveness of the moment— the capacity of events to disrupt patterns, generate new encounters with people and objects, and invent new connections and ways of inhabiting everyday urban life—and to the potential of urban histories and everyday life to be imagined and put to work differently, whether in the form of blueprints, models, dreams or hope for a better city, or in the capacity of random connections to generate the possibility of new ideas, encounters and collectives. (McFarlane, 2011a, page 209)

Within this context, the planner is charged with helping produce and accommodate a range of spatial explorations: activating the urban environment such that a variety of programmatic trajectories can be tested in temporary, strategic manners. Planning would thus involve creating a more permissive regulatory environment wherein particular zones could be designated that allow for the staging of various actions. The planner would act as curator, relying upon a creative brainstorming of options (which could easily engage stakeholder input). But rather then needing to make a deliberative choice between ideas - weighing (or modelling) their respective pros and cons - the planner would simply assist individual actors in provisionally testing one action after another – each in the 'light, quick, and cheap' manner associated with tactical interventions.

As tests are deployed, information and insights about particular urban strategies would be gained, with successes or failures evaluated based upon *actual* scenarios unfolding, not *forecasted* scenarios being deliberated. The planner would then help determine the evaluative metrics needed to determine an intervention's relative merit, success, or failure. These metrics could include both observational and statistical data: the number of people drawn to an area; problems created due to new traffic flows; reported business spin-off benefits; complaints reported due to incompatible neighbours – to list but a few examples. Based upon these metrics the planner would help guide subsequent iterations: perhaps an event attracts many people but also noise complaints and could therefore be tested at an alternative location or on an alternative date. The planner's role would become one of 'strategic choreographer', curating a series of urban 'happenings'.

While the project remains speculative (submitted to an 'ideas' competition), a growing number of more circumscribed precedents for this kind of schema have being adopted by various municipalities. Lehtovuori and Ruoppila (2012) discuss a variety of instances where municipalities actively employ tactical experimentation to test projects that can then be made permanent. Montreal, for example

recently used temporary trials to test the viability of car-free streets. Here, the first year is treated as a trial, whereupon *'the city observes how well the space is used, as well as the effect on motor vehicle traffic and local businesses'* (Schmitt, 2017). Over the long-term the city then makes permanent changes based upon these observations.

The proposed scheme echoes this process, but does so in a way that is, swifter, more extensive, and more exploratory. A series of civic permutations are unleashed in the environment across interacting parameters of space, time, and function. Each acts as an iterative trial: a probe investigating a particular time and place's latent potentiality to support specific functions. The success or failure of the probe in turn provides valuable information about a given environment's suitability for longer-term interventions. The initiative might 'die off' due to lack of support, 'stabilize' to become a permanent intervention that incurs greater investment (such as occurs in the Montreal example), or potentially replicate, as probes test the 'carrying capacity' of the urban environment to support a similar intervention across multiple sites. While speculative, the project also begins to point to how relational and tactical perspectives might meet and reinforce one another in urban settings. The next section elaborates upon this theme as it relates to field of Complex Adaptive Systems (CAS) Theory

§ 4.4 **Part 4: Urban Tactics as Complex Adatpive Unfolding-** *The matrix as 'engine of complexity'*

CAS theory is an extensive topic in and of itself, and space here does not allow for a full exploration of its themes. The interested reader can consult a wide range of easily available sources (Heylighen, 1999a; Holland, 1995; Kauffman, 1993), but a brief outline of key concepts is offered here. CAS theory has its roots in the natural sciences where it is used to study how bottom-up systems, composed of multiple actors or 'agents' are able to 'self-organize' in ways that generate fit, novel, and 'emergent' global properties in the absence of top-down control. These emergent properties are not predictable based on the inherent features of the individual elements of the system, but nonetheless emerge as a result of their interactions. Agents in CAS alter these interactions in response to information, feedback, and adaptation mechanisms, gradually retaining 'fit' protocols (Holland, 1995; Kauffman, 1993). CAS unfold in a non-linear manner - since a small change in circumstances at the agent level might, due to amplifying feedback, unfold so as to generate large differences at the global level. Accordingly, CAS concepts both correspond with and feed into a relational ontology – with stable entities being constituted by means of highly contingent relations and interactions.

The illustrative project serves to highlight ways in which tactical planning might be situated as a methodology used to optimize, accelerate, and streamline CAS processes within the urban milieu. The project suggests how tactical interventions might explore space, using strategies that echo evolutionary search processes. In this reading, propositions about 'fit' urban interventions are provisionally tested and the city is allowed to 'learn' (in an evolutionary sense) about which sites are best suited for particular programmatic functions. Further, unlike in relational approaches outlined earlier (which each engage aspects of CAS), potential spatial trajectories are explored *in situ*: the adjacencies that are plotted, the network proximities that are explored, and the actor/relations that are engaged are not rehearsed, *they are enacted* - in real places, in real times.
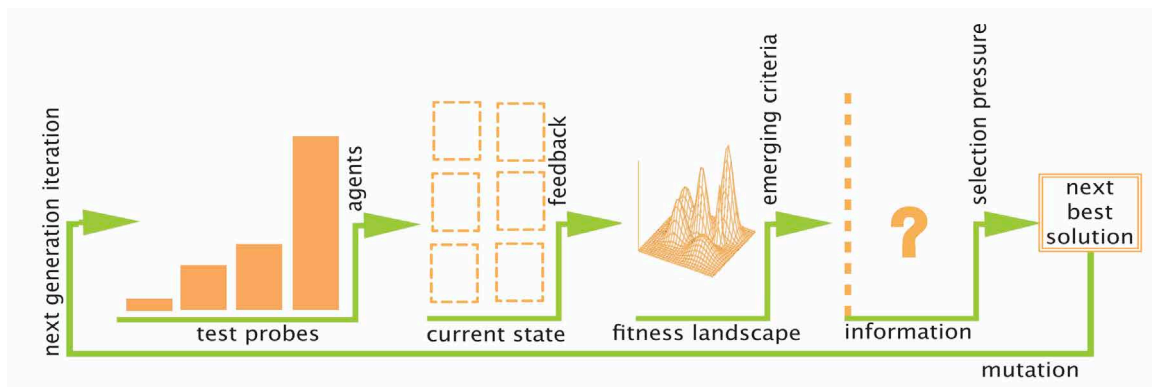
FIGURE 4.2 Iterations and feedback loops that support evolution of fitness:

Figure 4.2 illustrates how the matrix engages processes described in CAS theory. Here, each project or '*probe*' is conceptualized as an agent testing various programmatic/survival strategies within a given site. These probes are light, quick, and cheap (for example a temporary painted bicycle path), and able to quickly strengthen or abandon a given strategy. For every iteration (or state) feedback is gained about how particular sites (likened to niches) might be conducive to hosting particular programs (likened to species). Feedback is calibrated by monitoring various metrics that pertain to how well potential energy flows (people, goods, capital, etc.) are captured, transformed, and re-circulated within a given context.

Such criteria begin to give shape to what CAS refers to as a 'fitness landscape' (Pigliucci, 2008). This is a metaphoric terrain that illustrates how well a 'fit' exists between a particular agent strategy and the parameters of the 'niche' it finds itself within. Here, each 'peak' or site/niche within the landscape hold different latent capacities to support particular agent activities (although these latent capacities also change over time in response to relational forces). The landscape includes numerous peaks, representing many kinds of viable niches that agents might occupy. These have different heights, corresponding with different degrees to which they are viable for a particular behaviour. The more intensely viable a particular strategy is within a given context (meeting multiple criteria or metrics to a high level) the higher it sits upon a peak.[18]

To illustrate - perhaps shopkeepers in a particular locale are resistant to any kind of change and complain regardless of what is proposed: this would constitute a flat terrain within the fitness landscape. Perhaps a given site consistently draws large crowds for films on the weekend, but parking pressures preclude success on weekdays, this might represent a moderate peak, but one that can nonetheless be settled. Multiple iterations of spatial strategies bred through feedback combined with continuous probes of unexpected crossings of programs, times, and sites, together help generate data regarding each site's latent potentials and constraints. Here, observing whether or not a change in behaviour pushes an agent higher or lower on a fitness landscape (such as observing that the identical activity succeeds on a weekday but fails on a weekend) provides information that then steers the next iteration. As information is gained regarding the success or viability of a particular strategy (perhaps car-racing is simply unpopular, no matter where and when it is tested), selective pressure begins to

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18   Dittmer (2014, page 393), describes concepts analogous to fitness landscapes in Assemblage theory: possibility spaces with a range of capacities, but also certain tendencies, and 'singularities' (the peaks that tend to actualize).

weed out or displace weak fits while strengthening those that are strong. Functions begin to settle in these 'fit' locales, resulting in an emergent, functional, urban terrain.

The process of generating variants of programmatic strategies is thus analogous to exploring the fitness landscape, searching for emergent criteria for success, and gradually gaining feedback about the kinds of behaviours needed to address more and more fitness parameters (thereby climbing higher peaks), while simultaneously exploring multiple peaks (thereby ensuring heterogeneous programming). Emergent site strategies that inhabit high peaks by capturing site synergies in ways that attract crowds, support businesses, and avoid generating unintended negative consequences (noise complaints, traffic congestion, etc.), could then be permanently instated. Planners would monitor successes and failures, gain insight into the emergent criteria surrounding the fitness landscape, steer subsequent iterations and finally, help determine which interventions to make permanent.

§ 4.5 Conclusion

A successful and sustainable evolutionary system will clearly be one in which there is freedom and encouragement for the exploratory search process in behaviour space...a result of the existence of a capacity to explore and change. (Allen, 2012, page 87)

While tactical approaches have gradually entered into discussions regarding urban strategies, little to date has situated this approach within broader theoretical contexts. Where this has occurred, the emphasis has been on the 'grass-root' and empowering aspects of this strategy – the *'whos'* of enactment. Less attention has been paid to the '*hows'* of enactment: with tactical interventions situated as insertions within a pre-existing entanglement of relational forces that are subsequently altered and reconstituted. Further, while some tactical projects are conceived as prototypes that might become permanent, little work has reflected upon how this prototyping might be executed in a more systematic manner and thereby leveraged as a tool for planners. Finally, the links between tactical enactments and CAS processes, while noted by some, have not yet been clearly theorized.

The schema illustrated here is intended address these gaps. It positions Tactical Urbanism as a much more explicit strategy, capable of 'fine tuning' the placement of long-term interventions by leveraging the self-organizing and emergent capacities of CAS. Intended as a thought experiment, the details of the project need not be taken as literal. Rather, they point to how planning activities might be reframed such that they actively determine an area's capacity for future adaptation and innovation. Here, planners might,

...enhance the system's adaptive capacity by increasing the diversity of an area's spatial functions and structures. Obviously, not all developments will be equally successful in every area. We therefore speak of strengthening the 'pluripotential' of an area or region. It is a matter of stimulating the diversity of development that link in with the current potential of the area. Embracing diversity, and therefore increasing flexibility and the possibilities for responding to uncertainties, could create more opportunities for future innovations. (de Roo and Rauws, 2012, page 220)

The project outlines an alternative way of engaging with relational planning, offering a kind of *'engine of complexity'* (Marshall, 2012, page 191) that explores potential trajectories of city-making via a systematic exploration of territorial pluripotential. Within this framework, it is the *relations* in space

that ultimately determine what succeeds. But these relational potentials first need to be activated by planners and urban designers, in manners that enable '*a process that to some extent includes design, but is also evolutionary, involving generative, selective and adaptive processes'* (Marshall, 2012, page 205). CAS dynamics are actively engaged to steer these moves, fostering evolutionary strategies in explicit rather than implicit ways (Mehmood, 2010).

In this process, concepts of contingency, experimentation, and 'lines of flight' are embraced. But while these terms echo those invoked by Healey, Hillier, and Batty, here they are used to describe *physical* enactment rather than the *planning* of enactment, or a turn from *'discourse to practice'* (Whatmore, 2006), that is materially situated.

This explicit engagement between materiality and CAS has recently appeared in the work of others, notably Colin McFarlane, who considers both informalities and tactical environments (2011; 2011b), and Kim Dovey, who has framed an understanding of the material nature of informal settlements using CAS (2012). In other work I have also considered how specific instances of emergent districts provide insights into the relations between CAS and material potentiality. These explorations contribute new conceptual resources pertaining to the *situated* and specific nature of urban design, one that considers, *'urban planning as an act of interference*: a *practice of physical interventions in the materiality of the city'* (Boonstra, 2012, page 16).

While the schema provides an illustration of how CAS processes might be enacted in material contexts, clearly it is not intended as a 'cure all'. The schema brings other challenges to the fore, including questions surrounding the reframing of the planner's role, a lack of explicit guidelines on how projects might be selected as trials and instigated, and new deliberative issues surrounding the 'weighting' of evaluative metrics (though at least data associated with these metrics would be actual, not speculative). Further, the agility of the schema to be viably deployed within a range of planning contexts and for different kinds of physical interventions needs more consideration. Thus, while the schema might easily test locations for pocket parks (using moveable play equipment), how might it test transport routes? How long should tests run – the schema speaks about iterations of different duration, but what would determine the duration required to obtain viable feedback? And as the schema relies upon agent tests that can be 'light, quick, and cheap' must it be limited to small-scale works or might large-scale infrastructures be creatively partitioned into more 'nimble' and responsive components that test scenarios. While one might easily intuit how a bicycle route could be provisionally tested, more creative means would need to be deployed when considering 'thick' transport systems such as trains. Perhaps a permanent light rail transport route might be 'simulated' using traditional bus lines along temporary/painted lanes?

Finally, I present experimentation as an 'innocent' act – but if normalized, might it selectively be used to undermine safeguards within the planning process? Given, there have been fruitful experimental or 'special' zones created as planning alternatives (such as those accommodating New Urbanism codes in North America or facilitating experimental residential areas in Almere, Netherlands). But there have also been instances where 'exceptional' zones have been selectively designated in ways that undermine democratic access to space (Uitermark et al., 2017). If experimentation is adopted as a planning approach, then what safeguards must be in place to mitigate risk?

It is not my intention here to attempt to frame all of the limits, but rather to open up a conversation that speculates about the possibilities. The schema provides an illustration of how one might engage with planning on the ground, through and with contingency. My hope is that is suggests alternative tools for engaging with relational geography, while also bridging the methodological gap that separates the subject and the object of planning.

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Hypothesis: The Urban Environment as Phase Space

Introduction to Part 3

Part Two positioned the research by:

— Delineating what is being discussed when referring to a 'complex adaptive system';
— Identifying the scope of the current urban discourse surrounding CAS;
— Highlighting the area within this urban discourse that the Ph.D. wishes to engage more deeply (morphological unfolding);

Part Three now moves on to develop the core argument of the thesis - that urban fabric can behave as a complex adaptive system: evolving and adapting over time in order to manifest more 'fit' urban configurations. It advances this argument by:

A   Taking the position that shifting functional delineations of urban fabric (manifesting as global patterns or clusters of use), can be seen as an example of complex adaptation and emergence;
B   Hypothesizing that the physical composition of the urban fabric has a bearing upon the degree to which shifting delineations can occur and, by extension, the capacity the urban environment has to manifest emergent features;
C   Extending research insights from the field of Evolutionary Economic Geography (EEG) (which positions firms as agents in a complex system, and examines how these form emergent agglomerations) so as to introduce a more explicitly physical dimension to the factors yielding emergent behaviors;
D   Establishing (with reference to both EEG and CAS), a set of criteria regarding how urban fabric would need to perform in order foster emergent dynamics;
E   Illustrating how these performance criteria could be enabled through the curation of particular urban morphological features; and
F   Considering how real-world settings that incorporate such features may be shown to have exhibited emergent behaviors (through detailed case study analysis).

The first of the three articles in this section, *'Considering how Morphological Traits of Urban Fabric Create Affordances for Complex Adaptation and Emergence'*, argues that the built urban environment can be seen as a kind of 'phase space' of potentiality, one 'activated' to a greater or lesser extent (gaining 'degrees of freedom') depending upon its physical characteristics. The paper builds upon research in Evolutionary Economic Geography, which positions industrial clusters or agglomerations as the emergent manifestation of CAS processes that are driven at the individual 'agent' level of firms. The research elects to lean upon the work of EEG due to the fact that, relative to other urbanism and planning discourses, EEG is more directly attuned to the 'on the ground' factors that lead to physical emergence. As argued in the previous section, while CAS is influencing numerous urban and planning discourses, these generally employ CAS to frame ideas about planning discourse, or 'plan-making', rather than considering what happens once plans are made. By contrast, EEG examines the real-time, situated dynamics that play out on the ground through firms behaving as agents in CAS. Further, EEG engages CAS non-metaphorically, grafting CAS dynamics onto the behavior of firms by attuning to how they adapt, how they transfer information (learn), and how they become more fit through agglomeration dynamics.

The article argues that, while EEG has attuned to a wide range of factors informing how the physical appearance of industrial clusters manifests, the specific role that urban form might plays in activating these dynamics is under-theorized (and recognized as such by those in the engaged in this inquiry). The article therefore presents a series of illustrative examples of how urban form might enable or limit the way in which broader economic or social processes come to be 'anchored' in space. It examines urban form, not so much for what it looks like, but for how it enables certain key CAS dynamics to manifest. The paper argues that:

— Urban features can support or undermine the capacity to explore novel spatial trajectories (or phase space);
— Spatial 'cells' or 'chunks' of urban fabric can be considered as agents within a complex system;
— The efficacy of spatial cells to foster CAS dynamics hinges upon their functional size, their ability to support multiple functional states, and the relative number of simultaneous or 'parallel' spatial explorations the urban fabric easily supports;
— In order for groupings of spatial cells to evolve as a meaningful agglomeration, the fabric must in some way support the relaying of information (stigmergy), regarding whether or not cells occupy a 'fit' state.

For each of these points, I provide illustrative examples, frame the discussion with specific reference to CAS dynamics, and link the discussion to the existing EEG discourse.

The second article, *'From Form to Process: Re-Conceptualizing Lynch in Light of Complexity Theory'*, introduces a specific framework for conceptualizing urban form as an enabler of CAS processes. This framework employs terminology appropriated from Kevin Lynch, the intent of which is to provide a pre-existing and intuitive set of terms with which to consider morphological features from a CAS perspective.

The paper is framed as a critique of New Urbanist approaches to design. New Urbanism, which is currently having a huge impact on North American design practice, is a discourse which also attunes to urban morphology. It attempts to derive rules (or codes) with which designers might curate this morphology so as to produce 'good' cities (with 'goodness' being a normative, but under-theorized concept). The article attempts to flip the New Urbanism discussion on its head, positing that the movement should be attune more to what urban form does (insofar as enabling emergent, fit outcomes), rather than what urban form looks like.

Similar to the previous article, it discusses the nature of CAS processes - outlining analogous behaviors or processes as they manifest in urban settings. However, while the previous paper discusses the kinds of features that urban form needs to possess in order for CAS processes to be harnessed, this paper systematizes these features through a reworking of Kevin Lynch's categories of urban features (landmarks, paths, nodes, edges, districts). Each of these features (with the additional feature of 'cells' – an urban category also discussed by Lynch) is re-positioned as an aspect of the urban fabric that serves to enable dynamic CAS processes. Examples are provided which relate each urban feature to a particular CAS dynamic, be it:

— Supporting independent agency, (cells);
— Providing steering signals (edges);
— Channeling energy flows (paths); or
— Fostering information transfer at different scales (landmarks and nodes).

In addition, the formation of districts is seen as an example of emergence.

While the examples provided are general and do not pertain to an actual case (the subject of the next article) the intention is to introduce a framework that allows one to begin to understand how CAS dynamics might be supported within an urban context. Further, this framework is intended to make the connection between physical form and CAS dynamics more intuitive for designers (already familiar with employing Lynch as a design/analysis tool).

The last article in this section, *'The Grand Bazaar in Istanbul: The emergent unfolding of a Complex Adaptive System'*, provides a case study that examines the efficacy of the analytical framework to highlight emergent formal dynamics. It does so through a detailed analysis of the Grand Bazaar in Istanbul. Maps of the Bazaar, that highlight the programmatic configuration of shops decades apart, clearly indicate the clustering of similar product offerings and demonstrate that such clusters adjust, disappear, extend, or contract over the course of time. This clustering occurs in the absence of top-down control and can be interpreted as an example of emergent order. The Bazaar is chosen as the central case for a number of pragmatic reasons:

A   It offers an example of an urban fabric that has functionally shifted, over time, without top-down control;
B   Maps are available that document this shift, while also highlighting the existence of emergent agglomerations of functional clusters (similar to EEG agglomerations);
C   The cultural dynamics that have historically steered behaviors within this fabric are relatively well documented, allowing one to understand some of the ways in which urban dynamics may have been steered over time, and allowing an ease of comparing dynamics of the Bazaar with those explored within the EEG literature;
D   Turkish practices of hospitality mean that shop-keepers are amenable to discussing their history at the Bazaar. This is particularly the case during the low-season, meaning that I was able to obtain numerous in-depth interviews with shop-keepers, many of whom were able to comment on practices spanning back generations within their families. This results in the relative ease of obtaining interviews with sources able to comment on the dynamics of the Bazaar, thereby drawing parallels to the EEG literature based upon personal histories rather than my own conjectures.

The article employs both the general analytical perspective of EEG, and the Lynchian Framework set out in the previous article. Together, these provide an orientation for considering how emergent patterns within the Grand Bazaar may have, in part, come about through physical qualities that support CAS dynamics. Hence, the case study demonstrates how the Lynchian Framework might be meaningfully employed as a tool (or analytical lens) with which one can perform a new kind of urban analysis. Its efficacy is partially corroborated by the fact that the features it highlights echo the kinds of features that EEG researchers trace.

In researching this article, I relied, in part, upon historical literature and academic articles (listed in citations) pertaining to the Bazaar's economic, social and cultural aspects, Further, I relied upon site visits and questionaires in order to obtain a detailed understanding of how spaces in the Bazaar are occupied and shift over time. I conducted ethnographic observations (between 1997-2011), remote interviews with select Bazaar merchants in 2013, and field research and interviews in 2014, (with representatives from the markets for leather, jewellery, antiques, custom art, and carpets). It is worth noting that during the face-to-face interviews (approximately 25 interviews with both merchants that had been in the bazaar for generations as well as relative newcomers) no verbatim records were made. This decision was intended to facilitate a less formalized discussion (over tea, and over many hours), which note-taking or recording may have hindered. Instead, I recorded the essence of each interview as faithfully as possible immediately following each discussion. In addition, I attempted to have each merchant steer the content of these discussions, in order not to bias findings.

Despite relying on historic documentation, site observations, and site interviews, the analysis ultimately remains somewhat speculative. In the absence of a control group, there is no 'proof' that the dynamics I highlight using the Lynchian analysis are the actual dynamics that lead to the emergence of the Bazaar's stabilized districts. Furthermore, the analysis specifically sets out to 'find' particular kinds of dynamics and is therefore not neutral in any way (though the presumption of scientific neutrality or objectivity is increasingly suspect). Further, whether or not this form of urban analysis yields more insight than other forms remains ambiguous. What is clear is that a standard Lynchian analysis (which also sets out to 'find' particular urban features) would serve to highlight only particular formal qualities of space. By contrast, the alternate Lynchian analysis I propose highlights processes occurring in space: ones facilitated through the medium of form.

The hypothesis of this section is that the urban fabric can, indeed, behave as a complex adaptive system, but that this requires certain physical urban characteristics to be in place. It then specifies exactly what characteristics need to be in place and illustrates how each of these characteristics specifically contributes to CAS dynamics.

All papers within this section have been published in peer-reviewed journals.

5 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.

Introduction

1. 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 than 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)

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 artefacts 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 artefacts 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.

§ 5.1   Part 1: 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 behaviour. (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 transitory nature 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 behaviour, while always understanding these affordances in relation to human actors – as the *'nexus of human practices and material arrangements'* (Schatzki, 2005, page 465). Schatzki considers *'the layout of material settings'* (2003, page 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, page 197), play a role in constraining behaviours, 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 behaviour, 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 artefacts 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, page 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, page 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).

Part 2: 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 behaviours 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.

§ 5.3 Part 3: 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)*

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 analysed 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 discrete 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 behaviours (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.

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 centre: *'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'.*[19] 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 behaviours 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, page 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.

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19   Paraphrased from author's and subject's discussion (2010) as recollected by both parties in 2014.

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.[20] 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

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20   A detailed consideration of the Grand Bazaar's evolution is provided in Chapter 7.

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

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:

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

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 than fewer larger agents working sequentially, iteration by iteration. Hence the higher the number of agents (greater values for n)[21] 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.

§ 5.3.3 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, 2006a: 12. Thus, a medium for carrying information between charged particles is the electromagnetic field generated between them (Heylighen, 2006a), 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 behaviours. These prompts are reinforced or given 'weight' within an agent's perceptual environment when their density and preponderance increase. 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).

21　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)).

EEG research parallels this interest in stigmergy through analysing 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: page 36). EEG thus considers signalling 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 signalled: each path must be traced anew. The two material environments provide very different signals about useful behaviours 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. Neighbouring merchants observed that the sushi restaurant's tables were consistently full (its patio actually expanded) whilst theirs remained partially empty. One by one neighbouring 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.[22] 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 neighbourhood transition. Had there been no legible evidence of sushi's emerging 'fit' within the local context, there would have been no strategic cues for neighbouring 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

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22   Author's observations.

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 endeavour being externally subsidized - are cancelled out. Accordingly, while innovation *per se* is enabled by an urban fabric composed of functionally discrete 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.

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 than 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*'. These synergetic configurations, permit agents to '*differentiate their use of resources over time [...with...] minimal overlap in the resources they consume*' (Holland, 2012: 159).

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 neighbouring 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)[23] 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

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23   'Basins of Attraction' and 'Fitness Peaks' being different metaphors for the same concept.

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 discrete building block: these blocks can serve as independent units of space (restaurant, office, apartments); unify to span levels (single family dwelling) merge with neighbouring 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, page 216):.

§ 5.4   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, page 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, page 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 possible. 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.

6 From Form to Process: Re-conceptualizing Lynch in Light of Complexity Theory

Abstract

New Urbanism's disposition towards urban design emphasizes creating places that, in part, derive structure and meaning from 'imageable' components. These components resonate with the formal categories articulated by Kevin Lynch. That is to say, New Urbanist projects emphasize defined streets (edges) neighbourhood coherence (districts) civic buildings (landmarks) connective public open spaces (nodes) and gridiron street networks (paths). Lynch, however, deemed that such urban features arose from dynamic processes, whereas New Urbanists pre-designate formal features without full consideration of their functional dynamics. In order to better situate this notion of 'functional dynamics', this paper argues that urban settings can be considered as examples of Complex Adaptive Systems (CAS). The paper re-purposes Lynch's formal categories to discuss CAS dynamics in urban settings, with processes rather than forms providing the essential mechanisms with which to achieve the conviviality NU projects aspire to.

Introduction

Between the 1960's and 1980's a series of seminal texts were generated that continue to form the backbone of our contemporary understanding of urban form. These include works by luminaries such as Jacobs (Jacobs, 1961) Alexander (1979), and Cullen (1962). Each explored how formal characteristics of the urban environment support urban conviviality. But it is Kevin Lynch's work, Image of the City (1960) that remains perhaps the most influential text today. Lynch presented a set of clear formal categories that together evoke a sense of comfort, legibility, and meaning.

While much urban theory has been generated since, work has shifted away from these earlier concerns about the formal attributes of space - the physical aspects of 'plan making' - to focus instead upon procedural aspects of 'making plans' (Neuman, 1998). This, in part, has been due to an aversion towards discredited environmental behavioural approaches, as well as an increased sensitivity regarding underlying political, economic, and social forces that impact planning. While clearly productive, this turn nonetheless leaves a theoretical vacuum insofar as the enactment of physical

urban plans is concerned. Architects and Urban Designers, tasked with the 'on the ground' act of plan making, are left with little in the way of contemporary theoretical support. Emily Talen argues that, in the absence of a strong theory of form, this territory of 'plan making' is ceded to developers - *'actors who have no qualms about fighting for their preferences, even if they are narrow, short-sighted and in conflict with the public'* (2002, page 28)

In recent decades, New Urbanism (NU) has stepped into this theoretical void, offering an alternative to standard development models (Fainstein, 2000; Moudon, 2000; Schurch, 1999). The movement shares a number of general concerns with other planning approaches (affordability, walkability, mixed-use, sustainability), but is distinct amongst contemporary approaches in that it also attempts to redress perceived failings of the formal attributes of the built realm. While subject to numerous critiques, the movement is nonetheless exerting a growing influence on how plans are executed on the ground.

I wish to contribute to the NU debate by considering an overlooked shortcoming of its formal characteristics - one that pertains to a lack of rigorous investigation into the potential dynamics of form. To understand these dynamics I turn to an area of recent interest to planners, that of Complex Adaptive Systems theory (Holland, 1995; Kauffman, 1993). CAS investigates systems that 'self-organize' into coherent entities embodying synergies, differentiation, and functionality. CAS theory studies both the mechanisms that drive systems to self-organize, and various attributes of the structures that emerge. This paper specifically examines how particular morphological characteristics of the urban environment might support (rather than hinder) the self-organized unfolding of functional urban dynamics – ones that enable CAS dynamics to manifest.

The paper is divided into three parts. In the first part, I provide an overview of NU approaches, arguing that these privilege the generation of particular kinds of formal settings. While these settings may outwardly display the physical attributes of normatively 'good' environments, I argue that the performative dimensions they embody are under-theorized. In the second part I discuss Lynch's urban attributes (edges, paths, districts, landmarks and nodes) and introduce a framework for discussing these such that each feature corresponds to a particular functional aspect of a complex system. The third part of the paper provides specific examples of how Lynch's features might be reframed through this conceptual lens. For each aspect, I explain key CAS principles and provide illustrative examples that tie these to specific formal attributes that support an urban unfolding of CAS dynamics. This is intended to illuminate overlooked intrinsic, functional dynamics of urban fabric, rather than extrinsic, physical qualities. I conclude with a discussion on the implications of this framework for thinking about space, some reflections on complementary investigations, and avenues for further research.

A note regarding the presumptive ontology of this research should be mentioned. In presenting this framework, I realize that some may question the premise that a viable isomorphism can be drawn between the dynamics of CAS insofar as they unfold in biological or chemical domains, and processes of change and urban functionality that unfold in the built realm. Drawing analogies from one realm to another runs the risk of devolving into loose metaphors that generate more confusion than insight. The study of CAS is, however, predicated on the belief that a wide array of seemingly distinct processes unfolding in different systems are in fact alternate manifestations of dynamics that fall within the same general class (regardless of differences in the material format of how these dynamics are realized).

I concur with this reading. Therefore, as I unpack CAS concepts, I do not intend to suggest that urban systems are like complex adaptive systems and then draw metaphoric comparisons. Rather my premise is to assert that urban systems are complex adaptive systems: and then clarify the

mechanisms whereby they operate as such. As will be described, all CAS involve organizing flows through networked interactions of agents, who adapt their behaviours in response to environmental information about 'fitter' strategies, gravitate towards attractor states that reduce work or frictions, and eventually settle into emergent stabilized structures whose final form is based on contingent and historic processes. This paper broaches what these dynamics might mean if enabled by urban form: thereby making CAS dynamics in urban settings more 'legible'.

By using familiar categories (Lynch's framework), to broach unfamiliar territory (Complex Adaptive Systems), I aim to provide an intuitive framework that makes a CAS ontology more accessible to practitioners. My goal here is to describe why such tools might be productive and to introduce an overarching conceptual framework with which to begin to 'read' the urban fabric as CAS. Ultimately such a reading might be engaged to frame both urban analysis and design interventions. While space here does not permit me to go beyond introducing the framework and unpacking its relationship to CAS, the interested reader can review a case study where I consider the emergence of districts in an urban setting using the framework as a conceptual lens (see Self Citation 2016).

§ 6.1   Part 1: New Urbanism

New Urbanist principles have had a huge impact upon planning projects in North America and, increasingly, the world (Fainstein, 2000). Initiated by Andreas Duany and Elizabeth Plater-Zyberk, the movement aims to embody many of the principles espoused by Lynch, Jacobs, Cullen, and Alexander (Southworth, 2003). To achieve this, the Charter of New Urbanism (CNU) lays out 27 principles. Together, these codify practices that encourage sustainability, mixed-use, diversity, walkability, community, and transport options (Talen, 2013).

In geographer Michael Hebbert's survey of CNU principles, he notes that much of the Charter is consistent with contemporary urban 'best practices' and that it, *'could have been plucked from any current policy source - if the European Union were ever to frame an Urban Policy, this is how it would read'* (2003, page 196). This observation, while accurate, points to the somewhat generic aspirations of much of the CNU. To illustrate, the CNU includes statements such as: farmland and nature are important to the metropolis (CNU #3); streets and squares should be safe (CNU 23); natural methods of heating and cooling can be more resource efficient (CNU 26); development should support mixed-use/demographics (CNU 7, 11, 13, 16,); and sprawl should be counteracted through viable transportation options (CNU 12, 14, 15,). In this light, Rem Koolhaas' Almere masterplan could be seen as fulfilling the CNU's goals. The Almere project increases density, encourages walkability and public transport, provides a variety of housing types, and supports mixed-use.

That said, Koolhaas' project is decidedly *not* New Urbanist in formal execution. It is this *formal* aspect of New Urbanism that has attracted the bulk of NU critique - being denounced for its 'saccharine' or 'staged' appearance (Saab, 2007; Sorkin, 1992; Zimmerman, 2001). Other criticisms concern the social rather than formal successes of NU. These argue that the movement may exacerbate rather than alleviate sprawl (Weller, 2008); that it engenders homogenized rather than socially diverse neighbourhoods (Grant, 2007); that the projects are not necessarily more sustainable or walkable (Joh et al., 2009; Neuman, 2005); and that the CNU pays insufficient attention to the socio-political framework wherein design occurs (Veninga, 2004). Finally many question the movement's normative stance towards 'good' form (Moore, 2013).

Proponents of the movement counter that too much criticism has been levelled upon early examples of NU, which targeted wealthier demographics and are not representative of the Charter's aspirations (Ellis, 2002); that criticisms of early greenfield projects ignore the increasing number of projects currently being developed as infill (Trudeau and Malloy, 2011), that the demographic exclusivity of NU projects may simply mean that not *enough* of these projects are being built to satisfy market demand (Talen, 2000); and finally that, whatever complaints exist vis-à-vis the 'staged' quality of these settings, the environments are nonetheless based on sound, pragmatic precedents of good form, (Talen and Ellis, 2002) and certainly preferable to the banality of sprawl (Hebbert, 2003).

A great deal of ink has already been shed on these and other factors (Al-Hindi and Karen, 2001; Ellis, 2002; Grant, 2006; Kashef, 2009; Southworth, 2003; Talen, 2006b), and it is not my intention to repeat the discussions here. Instead, this article aims more specifically to reframe the critique surrounding the *formal* aspects of NU. While not mandated in the Charter, NU projects consistently recreate traditional typologies, codifying physical characteristics of previously successful urban places to derive rules for normatively accepted 'good' form. Here, focus is placed on the external, physical attributes of precedents. Proscriptions of form include the provision of public squares, gridiron street layouts, highly defined street edges and the employment of landmarks to terminate vistas. While the CNU holds a broader spatial agenda that goes beyond form, much of this is non-contentious. As has been noted, *'who would advocate for a sense of placelessness, or the absence of community'* (Veninga, 2004, page 463). In practice it is thus the formal character of NU that is both most associated with the movement (Jepson and Edwards, 2010), and its most contentious aspect.

Typically, critiques of NU formal character either reject the 'authenticity' of these environments, or the normative ideas about 'goodness' they embody. New Urbanists generally respond that there is a 'common sense' appeal of the codified environments: that they are pragmatic, representative of sound urban principles, and based on historic precedents. Indeed, it is difficult to argue against the qualities of NU environments (recalling Charleston, Savannah, etc.). Geographers also recognize the legitimacy of a desire for nostalgia, for 'a sense of place' and 'belonging', that somewhat problematize charges of 'inauthenticity' (Aravot, 2002; Jarvis and Bonnett, 2013). For even as cultural critics denounce the movement's sanitized and pastiche version of conviviality (Sorkin, 1992), this critique rings hollow for a public who, understandably, prefer pleasant streets with pretty facades to the proliferation of garage-fronted homes in suburbia or the anonymity of strip malls. Thus, to dismiss the sensibility that drives the desire for NU environments is not in itself productive (Brain, 2005).

I seek to avoid an overly simplified binary discussion that pits the desire for 'authenticity' against that of 'at-homeness'. Instead, I wish to shift the discussion regarding form to one that current academic debates have not yet fully engaged: that of morphological productivity. Thus, if proponents of NU are correct in defending the overall aspirations of the Charter, then the question remains: do the environments being created in fact correspond with the common-sense 'good form' they attempt to embody? Ultimately, I wish to look more closely at *why* particular formal urban elements or morphologies might be considered 'good'.

Here I take partial cue from Jane Jacobs. Jacobs (often cited by NU for her championing of walkable cities), disavows NU neither on the grounds of its aesthetic limitations, nor on its perceived failure to achieve some of its other aims (affordability, mixed use, etc.). Instead, she argues that the movement fails by lacking an understanding of the role urban dynamics plays in engendering successful places. In a 2002 interview she states,

'The places they have built, they don't seem to have a sense of the anatomy of these hearts, these centres. They've placed them as if they were shopping centres. They don't connect.' She continues, '*big*

*cities have a lot of main squares where the action is, and which will be the most valuable for stores and that kind of thing. They're often good places for a public building -- a landmark. But they're always where there's a crossing or a convergence. You can't stop a hub from developing in such a place. **You can't make it develop if you don't have such a place.** And I don't think the New Urbanists understand this kind of thing. They think you just put it where you want.* (Steigerwald, Jacobs interview, 2001 emphasis added)

This criticism, argues that NU generates too static a 'product', rather than embodying 'an evolving process of human development' (Neuman, 2005). Here, NU is questioned not because of its scenographic qualities per se - that they are 'kitsch' or 'inauthentic' - but because the formal components are insufficiently grounded by underlying forces.

More germane to this article, a number of scholars (including Jacobs) suggest that the environments New Urbanists espouse might better be understood through an analytical lens that employs Complex Adaptive Systems perspectives (Dovey and Pafka, 2015; Neuman, 2005). CAS supports many of the stated aspirations of New Urbanists. Emily Talen, for example identifies both the need for incrementalism (2006a), and 'design that enables diversity' (2006b). In discussing each, Talen cites Jacob's reading of the city as a complex system – but the way in which these aspects might be operationalized remains vague and tends towards a focus on external characteristics. The framework offered here may help remedy some of that vagueness, by identifying the underlying material conditions that support processes which engender 'good' urban settings.

§ 6.2   Part 2: Reconsidering the Image of the City

Traditional definitions [of urban design] constitute descriptions of perceptible surface structures […] a bit like trying to define gravitation in terms of apples falling to the ground, by what colour the apples are, what type of apple, how they compare to apples falling off other trees etc., in the absence of a supporting hypothesis. (Cuthbert, 2007, page 185)

Kevin Lynch's Image of the City (1960), provided a clear set of terms used to both analyse and design civic environments. His framework of edges, districts, landmarks, paths and nodes proved highly productive, resonating strongly with our perceptions of the built realm. Admittedly, the very act of categorizing the urban realm can be viewed as suspect - seen as part of the modernist project of classification that ignores ambiguity and undermines multiple readings. Notwithstanding this critique, on a pragmatic level, Lynch's categories continue to exert a huge influence on the ideas and actions of designers and planners. As late as 2013 '*Image…*' remained the most consistently recommended text assigned in Urban Design reading lists (Araabi, 2015). It is one of MIT Press's top selling publications of all time, and its formal categories remain the most commonly deployed tools in producing urban analyses – an exercise often predicated upon identifying the various morphological characteristics that Lynch - as part of the sensibility of his time - neatly categorized.

Despite the method's broad dissemination, Lynch himself was highly critical of the way his framework came to be used.[24] He laments how the terms erroneously, *'elicited a static image, a momentary pattern'* (1995, page 252):

It seemed to many planners that here was a new technique – complete with the magical classifications of node, landmark, district, edge, and path – that allowed a designer to predict the public image of any existing city or new proposal. For a time, plans were fashionably decked out with nodes, and all the rest [...] the words were dangerous precisely because they were useful. (1995, page 251)

Lynch intended to codify formal elements that arose from dynamic urban patterns – ones that became grounded and formalized at particular urban confluences. It is thus important to distinguish between Lynch's more nuanced views, versus what might be described as 'Lynchian' tactics: an appropriation of his work that reduces much of the complexity of the city to visual shorthand - to compositional rather than operational qualities. Arguably, the NU approach to urban composition is Lynchian in its sensibility[25] (Hamer, 2000). Thus,

DPZ's vocabulary of spatial units reflects a distinctly Lynchian influence. Neighbourhoods are linked to and divided from other neighbourhoods by 'corridors' or paths created by major roads and/or natural features. 'Districts' are ensembles of streets or even entire neighbourhoods dedicated to specialized nodal activities like entertainment or commerce. (Rutheiser 1997, 122)

It would appear that, notwithstanding other aspirations, New Urbanists craft plans that codify the 'momentary patterns' Lynch objected to, incorporating 'textbook legibility' (Ford, 1999, page 254). And while New Urbanists argue that what matters is not the forms in and of themselves, but the social interactions these forms support, this is often not borne out in practice. The NU community of Cornell in Markham, Ontario **[Figures 6.1, 6.2 and 6.3]** provides a case in point. Here a corner intersection is given the formal expression of a tower - a legible 'landmark' and, if we are to believe the rhetoric, a natural marker for gathering. But the tower, situated above a health clinic, is vacant: no clock, no bell, and no broader intrinsic significance for the public realm. The building, seemingly oriented to both sides of the street corner, is blanked out on one side - with little correspondence between the tower as 'signifier' and the gathering functions it signifies. The lower level shop windows, which suggest a 'grain' of urban fabric, are blank, providing no street interface.

If the public spaces, landmarks, walkable streets, density and scale, and architectural differentiation espoused by NU are seen primarily as the physical attributes of liveable places, then it would appear that NU have adopted a 'Lynchian' sensibility, one that identifies and replicates the extrinsic expressions of these formal settings but is less articulate concerning how these operate at an intrinsic level.[26] This paper suggests an inversion of how we think about Lynch's categories, such that they exist not as formal ends in and of themselves, but insofar as they engender or are manifestations of certain types of unfolding dynamic processes. To better understand the nature of these processes, we turn to CAS Theory.

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24   Lynch argued his later attributes - vitality, sense, fit, access and control - providing a more nuanced means of understanding the process of city-making. However, these failed to gain traction to the same degree as the earlier categories presented in 'Image...'.

25   This sensibility towards formal character is not limited NU, but their work is currently most influential. Other approaches include the Townscape movement (Cuthbert, 2007).

26   Landscape Urbanism is engaging a similar discussion, aiming to distinguish between landskip - the pictorial or scenographic aspects of an environment, and landschap - the functional or performative aspects of place (Corner, 1999a; Weller, 2008).

FIGURE 6.1 Tower: Note absense of foot traffic (Google street view image)

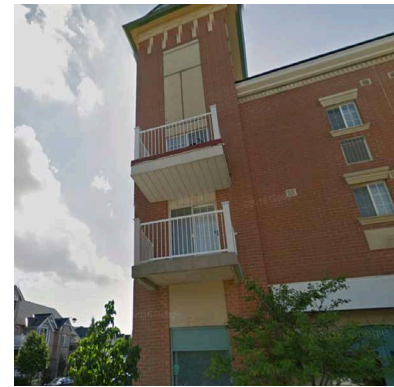FIGURE 6.2 Empty storefronts; (Google street view image)

FIGURE 6.3 Blanked out windows in corner tower (Google street view image)

Part 3: Reframing Lynch to consider CAS Dynamics

The valued city is not an ordered one, but one that can be ordered – a complexity whose pattern unfolds. (Lynch 1995, 252)

In recent decades, a broad range of planning approaches have turned to Complex Adaptive Systems Theory for inspiration and insight (Batty, 2007b; Marshall, 2008; Portugali, 2000). CAS is attracting attention because these systems exhibit order derived from the bottom-up, which both empowers stakeholders and may remedy the ills of top-down approaches. Further, a CAS ontology is one attuned to processes, indeterminacies and flows, in contrast to the Modernist focus on objects, certitudes, and stasis.

§ 6.3.1 **Embodied CAS Processes:**

Complex Adaptive Systems typically are composed of evolving networks of interacting Agents whose coordinated behaviours generate emergent and contingent phenomena. Agents might be stocks in a market, molecules in a chemical reaction, birds in a flock, or in our case, built fabric in the city. Order in CAS emerges due to processes involving these agents, as they enter inter Networks of interaction with other agents steered by the presence or absence of various kinds of driving resources or energy (Holland, 1995). Within these networks, Information differentials (Bateson, 2002) help steer agent behaviours towards regimes where the 'costs' of action (or frictions) are minimized (Casti, 1979, page 4). The act of minimizing resistance pushes agents towards specific Attractor States (Lansing, 2003) such that their actions seem coordinated. Over time, Agents eventually coalesce into self-organized emergent global patterns – exhibiting structure and behaviour that are not predictable when considering the capacities of the individual agents themselves (Heylighen, 2011a).

In CAS, relationships are primary whereas the 'objects' - or 'form' of the system - is derivative. This flips our standard way of thinking, where urban relationships are seen as being derivative of primary forms. Correspondingly, if one were to consider Lynch from a CAS perspective it would involve

'inverting' his terms such that they become emblematic of processes (described above), rather than formal features [Table 6.1].[27]

MODIFIED LYNCHIAN URBAN FRAMEWORK			
Formal Features	**Related CNU**	**Functional Role in CAS**	**Ecosystem Examples**
Paths	Street Networks	Distinct and pleasant walking streets, transport options (CNU 8, 10, 12, 14, 22)	Evolving Networks that effectively channel flows or agents.	Channels of resources flowing through an environment (streams, sun-paths, ground nutrients, foraging trails).
Cells	Typical grain of urban fabric (shops, homes, etc.)	Provision of finer grain (walkable) built fabric density (CNU 15, 21,24,27)	Multiple, parallel Agents testing strategies that maximize resource use and minimize frictions	Evolving populations of species exploring fitness strategies (birds, insects, mammals).
Hubs (Landmaks and Nodes)	Gathering places (plazas, schools, churches, squares, etc.)	Differentiation in hierarchies, provisional of public gathering spaces (CNU 16, 18, 23, 25)	Emergent Attractor States where flows tend to gravitate, regardless of their origin. Sites of minimum energetic resistance. Occur at multiple scales.	Sites where flows converge (nests, ant hills, dens, etc.) Areas with high densities of resources – ie. Food /fuel source sites (ponds, nutrient sinks, etc.).
Edges [1]	Urban Surfaces: Public Private interface: (Street displays, hard or soft surfaces)	Clear and cohesive street boundaries (CNU 6, 17, 19)	Information signals that mark productive agent behaviors and broadcast and break potential system symmetries.	Signals coordinating behaviors within a species (pheromone trails, mud deposits in termite mounds, geometry of honey cells in hives, etc.).
Districts	Complimentary zones or clustered use areas (antique districts, gallery precincts, etc.)	Neighborhood and District coherence (CNU 5, 10, 27)	Self organized emergent Global Patterns (assemblages) that efficiently circulate and coordinate resources, minimizing frictions.	Patches of species synergetically inhabiting a particular ecosystem environment.

TABLE 6.1 Modified Lynchian Analytic Framework

The remainder of the paper unpacks this table, arguing that the emergence of successful places is predicated upon the presence of information and resource flows (networks/paths); the built fabric's ability to relay signals (information/edges); the capacity of the fabric to alter in response to that information (agents/cells); the presence of hubs in the fabric where flows and resources are effectively entangled (attractor states/hubs); and finally, the capacity for distinct and symbiotic assemblages (emergent patterns/districts) to manifest as a result of these underlying dynamics. By re-conceptualizing Lynch's framework to highlight these CAS processes, we can re-examine NU formal environments in a new light: not for how they look, but for how they perform.

Landmarks & Nodes (Hubs) = Attractor States

Consider a classic example of CAS morphogenesis - that of Benard rolls (Heylighen, 2004). Here, water molecules in a petri dish are subjected to external heat. As temperature increases, individual water molecules become excited into random motion. Some molecules rise while others fall,

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27   I am not the first to use Lynch's systems to evaluate NU projects. Ford (1999) does this in an interesting piece but his objectives differ.

creating pressure differentials and drag dynamics in their vicinity. These drag forces impact upon the motion of neighbouring molecules, such that they are pulled into synchronized movements. At a certain energetic threshold of heat (termed a bifurcation point) the molecules 'choose' between two energetically equivalent potentials – inward or outward rolling patterns – which all molecules in a region obey. This CAS is composed of molecules (agents), the boundary of the petri dish (allowing for dissipative heat transfer), a heat source (energy), and the drag force dynamics generated between molecules as they agitate (interactions). Looking at the resulting clear pattern of rolls, one might infer that the rolls constrain the movement of the molecules. But this would be an error: the roll direction is an efficient emergent structure that is generated by system dynamics.

Now compare this example to that of a landmark in the urban fabric. Is the form of a landmark what engenders 'order' within the environment, creating the conditions whereby legible pattern emerges? Or is a landmark the physical manifestation of underlying urban forces already possessing an order – an emergent outcome of interactions that coalesce as this particular physical form?

Let us consider this question in relation to the broader subject of nodes and landmarks or hubs in Complex Systems. The World Wide Web, another classic example of a complex system has a structure comprised of hubs and spokes. Hubs represent particular websites (agents) and spokes are the paths that link information threads of the network together (interactions). Variable web traffic intensities (energy) between sites enable the system to differentiate (with some hubs 'feeding' off clicks to become highly connected, as others becoming peripheral). A fractal topology of the web emerges because new websites try to link to already 'well connected' entities such that, in effect, the rich get richer. This process of growth and preferential attachment leads to a network with a fractal topological structure: the so-called 'fingerprint' of CAS (Strogatz, 2001).

Analogous dynamics play out in cities, where large cities tend to become larger as they draw a disproportionate number of new entrants compared to smaller ones (Bettencourt and West, 2010). 'City Rank Size' distributions are the fractal manifestations of this process. Similar regularities are observed in a myriad of CAS including stock markets, academic citations, and earthquakes. This means that CAS exhibit few 'large' entities (high stock prices, highly cited authors, major earthquakes), a midrange number of 'medium' entities, and a large number of small entities (small tremors, low impact papers, penny stocks).

Wikipedia is an example of a 'large' entity in the network of the Web: a well-connected hub that continuously grows due to reinforcing feedback loops. Given this reinforcing feedback, it would now be very difficult to displace Wikipedia as a central hub: its position as an attractor has been consolidated, and subsequent system dynamics are now 'enslaved' (Haken and Portugali, 2003). In the sciences, attractors are points to which a system will likely converge, due to the fact that these states requires the minimal energy output to reach (Heylighen, 2004). For example, no matter where a swinging pendulum's path begins it eventually converges towards the state of least resistance (hanging vertically). Similarly, a ball spun from the top of a circular vortex (often found in science museums) circles in a series of loops until settling into the lowest section of the vortex – the 'basin of attraction'. While both the nature of the attractor and the specific mechanisms through which each system 'finds' the attractor differ, each system nonetheless plays out through 'minimizing processes' the dynamics of which reduce overall resistance (DeLanda, 2005).

What kinds of minimizing processes might occur in cities that result in attractors? Imagine navigating a district, trying to get from here to there. Certain streets will result in dead ends, multiple turns, switchbacks, or steep climbs: points of resistance. This is fine if we wish to expend energy ambling along – if that is our goal. But if our object is to arrive quickly to a destination, then we will look for

routes with minimal frictions: the smoothest flows, most direct connections, and swiftest means by which to switch to faster modalities (such as train connections). Regardless of our initial starting point, multiple routes will naturally converge towards particular paths satisfying these conditions. Certain locations will be positioned at points where these routes intersect and these crossings will hold the propensity to manifest as landmarks or nodes (for an interesting discussion on how nodes manifest, see also Mehaffy et al. 2010).

New Urbanists recognize that successful urban environments hold important hubs: parks, plazas, squares and gathering spaces (echoing Lynch's landmarks and nodes). But there is a difference between a node created from a blank slate, meant to foster interactions, versus one emerging as a result of interactions. In historic contexts, plazas and gathering places are situated at river or transport crossings, places where urban flows - goods, information or people – pause and intersect. Here, flows either continue on their trajectory or are altered and reconstituted. In that moment of pause, 'thick' flows can be dispersed at the local scale, allowing markets or distribution centres to emerge. The greater the range and scale of converging modalities the more intensely these centres are supported (Read, 2005). While these junctures might initially emerge from one of many potential locations, once present, their location is 'enslaved': they develop 'weight' as an attractor of new flows (in the same process of growth and preferential attachment described earlier).

Rather than tracing the trajectory of flows, NU 'stages' urban pauses by designating a particular node in the urban fabric as a gathering place. What is unclear is how these placements go beyond compositional exercises to correspond with actual flows. Victoria Commons, a NU project in Kitchener, Ontario serves to illustrate. Promotional literature describes a 'Piazza' - formalized as a large public square, complete with fountains, café tables, and clock tower. But inspection of the plans reveals no cross routes linking this node to the broader neighbourhood. The piazza is framed by three apartment buildings, but with insufficient density evidenced to generate the kind of conviviality illustrated in renderings. Presumably grade level retail is included as part of the mixed-use. But what makes this retail a destination? It is dislocated from the broader flows and does not form part of day-to-day movement networks. While NU handbooks do discuss that trajectories should have a destination, and that this *'should be useful or in some way rewarding'* (Plater-Zyberk et al., 2003, page 82), this does not seem to be borne out in practice. The web literature states that *'the Piazza **beckons** pedestrians'* (emphasis added), highlighting the intention to create an attractor that acts as a magnet for interaction. But attracters in CAS do not 'beckon'. Rather they emerge when underlying conditions are right.

Attractor states in their civic medium vary – some are nodes, others landmarks, and the distinction is muddy.[28] In our proposed framework, Nodes refer to smaller urban junctions that foster casual and tacit encounters (coffeehouses, barbershops, etc.). Landmarks refer to sites where broader flows consolidate such that they can then be reconstituted in synergetic interactions (churches, central markets, train stations, etc.). Landmarks are thus sites that entrench and stabilize productive routines, while Nodes are sites that permit provisional testing of new associations that foster innovation. Flows will thus converge both at highly connected and maintained 'global' pipelines or more provisional 'local' hubs (Bathelt et al., 2004a). Both are necessary for the successful evolution of a complex system, but more importantly, these synergetic sites are contingent: best understood as emergent outcomes of flow trajectories.

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28   This same ambiguities exist in Lynch' s original terms (Dovey and Pafka, 2015, page 3) – is a plaza with a church a landmark or a node?

TOC

Paths = Networks

Consider another classic CAS example: ants forming paths to seek food (Deneubourg et al., 1990). Individual ants have no knowledge of global patterns, but nonetheless undertake behaviours that result in coordinated path formation. Each ant explores its environment at random, but upon discovering food will 'signal' the presence of an energy source through depositing pheromone traces. These traces thereafter constrain subsequent ant behaviour. The stronger the trace (which decays over time, allowing better food sources to maintain stronger trails), the more ants will follow a given pathway, thereby generating a reinforcing feedback loop whereby an emergent pathway manifests. Here the CAS is composed of ants (agents), food sources (metabolic resources) and pheromone signals that transmit information from one ant to another (interactions).

A latecomer to the scene, observing the pathways, might find it difficult to imagine that these routes do not direct the ant's movement towards resources, but are instead a derivative structure that emerges due to the dynamics of the search process itself. New Urbanists, who observe the pathways of 'great city streets' attempt to emulate their physical characteristics - cross-section, length, distances between buildings. If we consider the formal entity 'path' to be successful because of these extrinsic qualities, then NU pattern-books suffice. But while providing a clear pheromone trail for ants (in the absence of food at its termination), would compel ants to follow this trajectory, it would not make the pathway functional. If we instead consider 'paths' to be emergent network links, ones that manifest to support inherent flows, then we would employ other research methods to understand their properties.

In historic cities, networks of large, medium and small streets emerge through reinforcing cycles of use, and exhibit fractal distributions. Within an area, streets initially attracting a slightly higher number of users will attract more services. These services in turn draw new users who reinforce the pattern such that particular streets gain prominence within the network. Considered in this light, the approach of designating a formal or fractal hierarchy of streets a-priori, without reference to the dynamics of flows being channelled, is as counterintuitive as predetermining website links on the Internet. No one determines the structure of the Internet: its composition is shaped by the evolving dynamics of its use. While NU certainly attempts to make streets both legible *and* functional, it is noteworthy that many examples of their projects include highly legible paths while the flows these are meant to channel remain absent. Simply imitating fractal distributions in the absence of underlying dynamics presents only a 'picture' of complexity – not complexity itself.

Edges[29] = Information

CAS are composed of agents whose actions alter in order to better achieve a particular goal (finding food, processing energy, seeking knowledge, etc.). Populations of agents therefore benefit if they can tune their work in productive synchronization - if useful information can propagate within the system. In many instances this synchronization occurs directly, through neighbour-to-neighbour signals, such as when flocking birds coordinate their movements. In other cases, coordination occurs indirectly with agents leaving a trace or 'stigmergic signal' of their actions within a common environmental 'medium' shared by all agents (Heylighen, 2011b). This medium acts as an information repository, a coordination device that both records and prompts agent behaviour. Returning to the example of

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29   In Lynch's original framework Edges are district boundaries, but subsequently the term was appropriated to discuss street facades qualities. This usage proves more useful for this discussion.

ants, pheromone traces guide ant behaviours. But this marker requires both the pheromone itself (the information), and the shared medium of the ground to act as repository for this trace [Figure 6.4].
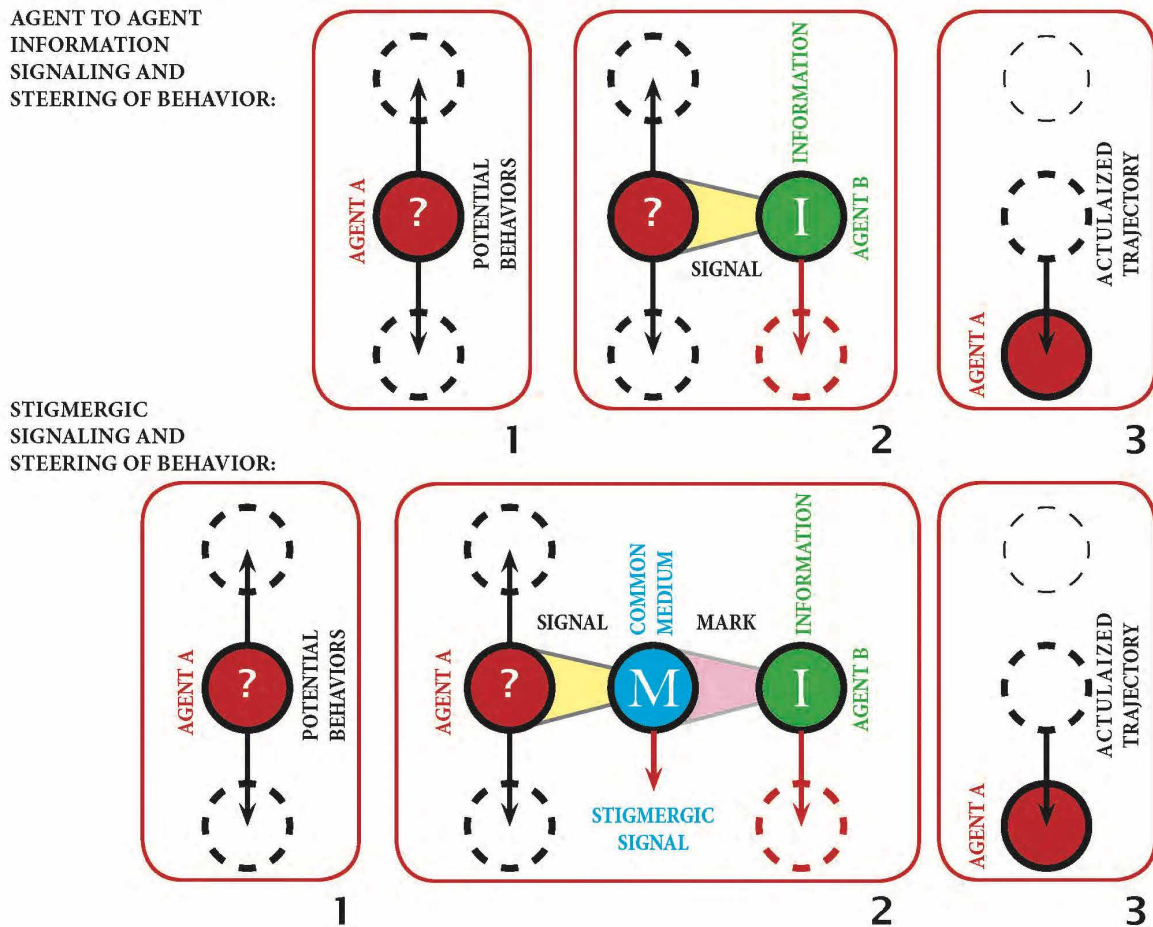

FIGURE 6.4 Agent signalling and stigmergy

When navigating a city, the presence of visual cues helps direct movement– providing information about how to proceed. A tourist wandering amongst shops may round a corner where uses shift to homes, thereby backtracking to maintain a trajectory providing a continuity of shopping experiences. Similarly, a shopkeeper might re-locate to be near similar successful businesses, hoping to capture desirable flows already converging in that region. The environmental medium of the urban fabric thus helps *signal* how one occupies or navigates space.

While this may seem self-evident, what is often overlooked is that certain urban fabrics have the capacity to transmit information better than others. This point is not trivial. A modernist multi-story building may house offices, apartments, or shops, but this information is subsumed under the cover of blank walls. Similarly, suburban developments of near identical homes, or cookie-cutter apartments create environments almost void of information. Here, *difference* – the key to information (Bateson, 2002), is absent.

Consider how information traces are left when walking across grass in a park. Here, traces left on the grass record *actual* lines of movement, rather than those *pre- designated* on sidewalks. The *act* of walking traces a trajectory along the ground, but it is the *displacement* of the grass (as a common medium) that conveys information about this trajectory to others.[30] By contrast, a concrete plaza is incapable of storing and communicating the act of walking: as a medium it is mute.

Similarly, fixed park benches cannot record the best place to either seek or avoid sun, but moveable chairs - clustering in microclimates that might otherwise go undiscovered, re-orienting to capture views, consolidating in quiet areas for conversation - record a range of 'fit' patterns of uses. While NU projects incorporate the *function* of seating - park benches installed in regular rhythms along sidewalks – the benches often seem to be employed as urban texture or décor, as choreographing the *idea* of use, regardless of site conditions.

Like malleable grass or moveable chairs, the boundary interface or *edges* of the city can record and relay patterns and propensities. The individuated street facades of Hong Kong, or the street-markets of Istanbul are information rich (Wohl, 2015). This information gains resolution when it becomes increasingly distinct, such that subsets of function – galleries, restaurants, retail, etc., become discernible. Street signs, furniture, window-displays, and the appropriation of the sidewalk edge, all provide armatures that enable the etchings of urban life to be inscribed upon them, whereas blank modernist contexts do not **[Figures 6.5 + 6.6].**

FIGURE 6.5 Hong Kong Street
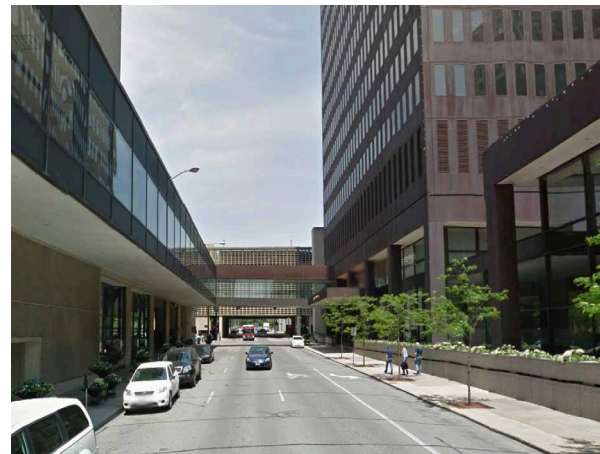
FIGURE 6.6 Blank Modernist Street

While NU catalogues the physical characteristics of 'great city streets' they emphasize the optics (detailing of the street edge, windows at grade level, frequent entries and variation along a city block) of successful places. But perhaps the most important and overlooked characteristic of great streets pertains to the role of the public/private interface at the street edge, not because of its physical 'look', but rather its performative capacity to transmit coordinating information.

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30   There is some confusion around 'agency' as understood from the social sciences where it implies volition. The term is used differently in CAS where water molecules, stocks or websites can each be considered as agents. In this example grass has no 'agency' per se, but nonetheless is s a carrier of information relevant to agency.

Cells = Agents

In order to appropriate Lynch in a manner that supports a reading of civic CAS dynamics, it is necessary to supplement his spatial categories with one additional trait – that of the urban cell. While *'Image…'* does not refer to this aspect of the urban fabric, Lynch later introduces the concept of 'Grain' which he describes as, *'typical elements and densities […] differentiated and separated in space'* and *'a quantity of a given type'* (Lynch 1995, 362). 'Grain' references the ubiquitous urban texture of a particular neighbourhood (described as 'tissue' by Kropf (1996)). Depending upon the setting, the scale and density of built grain might be that of residential homes, apartment blocks, town-homes or big box stores. The term 'Cell', introduced in Table 1, refers to the individual elements of the built fabric that aggregate to form the texture of this grain. The 'cell' component of a given district is then made analogous with the 'agent' component in CAS.

Agents within CAS work in parallel to improve performance by optimally channelling their respective system's resources (Holland, 2006). They can replicate, die, alter states, or meld with other agents. Similarly, a particular slice (or cell) of urban fabric might cycle through a series of functions – restaurant, dwelling, office - before 'discovering' ideal neighbourhood synergies. However, the resistance involved in performing these cycles may vary, depending upon the nature of the fabric. Does it require demolition or costly renovations prior to each iteration? Is the built fabric 'stiff' or 'supple', flexing in a reasonably plastic manner to enable new uses?

While a plethora of social factors inform which particular uses are most viable at a given site, there is also a *'differential in the urban surface'* (Read, 2007a) where certain activities are more *possible*. Thus, *'in certain places it is possible (or coherent) to imagine certain things, where those things may not be imaginable (or coherent as imaginations) somewhere else […] A location where such a coherent imagination may lead to realization is precisely and practically an 'enabling place''* (Ibid).

I argue that certain kinds of urban fabric of 'cells' are more *enabling* for the manifestation of possible states than others – offering a greater range of *affordances* or *capacities* (Gibson 1986; see also DeLanda 2005). These capacities include the ability to accommodate a range of functions, and to easily expand or contract as circumstance dictates (for example by aggregating with neighbouring units). The divisible cells of canal buildings in Amsterdam, for example, are responsive to changing political, economic and social circumstances - easily morphing, floor by floor, from warehouse to museum to brothel (Wohl, 2016a). The resultant neighbourhood diversity is not something *orchestrated* by planning, instead it is *manifested* because enabling places are present.

New Urbanists note the importance of mixed-use, and occasionally discuss the importance of creating 'flex-house' infrastructures that can evolve organically (Plater-Zyberk et al., 2003, page 53) but in practice projects tend towards proscriptive designations of pre-established balance of uses. A more viable mixture might be achieved by creating built environments that afford the possibility of shifting over time - testing uses and continually rediscovering the appropriate mix of functions in a given setting. By conceptualizing 'cells' of urban form as performing in ways similar to agents in CAS, the fabric of the city might continuously co-evolve – shifting in response to the dictates of circumstance.

Districts = Emergent Patterns

In CAS an emergent structure is one where agents have coalesced into stabilized patterns of interactions that effectively process and partition that system's resources (Heylighen, 1989). Termite mounds provide an illustrative example. The mounds are subdivided into distinct spatial districts,

including areas for venting, storage, a lair, and nursery. Initially random form-shaping actions of the termites imbue the mound with information, which thereafter cue subsequent actions – creating a cycle whereby emergent structural features constrain the behaviours of the termites encountering the mound at any given moment (Bonabeau et al., 2000). As the architecture develops, the mound incorporates increasingly distinctive functional variants. The dynamics that lead to the morphogenesis of this structure ensure that the scale of each variant is suited to the environmental conditions and constraints of the colony.

An outside observer, looking at the structure of the mound might remark upon the perfectly organized and distributed functional *districts*. Yet the termites have no overall cognition of what they are creating. Nonetheless, a coherent physical entity emerges, with specialized districts that are in equilibrium with the needs of the colony. Order is achieved *from the bottom up* due to the interactions of multiple agents - each seeking to optimize the resources entering the system and each constrained through interactions with the emerging mound itself.

I propose that Lynch's 'Districts', be reframed to correspond with this concept of *emergence* - something performed (rather than produced), as the natural manifestation of intrinsic forces. Rather than simply exhibiting vitality, these districts would be the product of an urbanism, *performed over time,* which embodies vitality **[Figure 6.7 + 6.8]**..
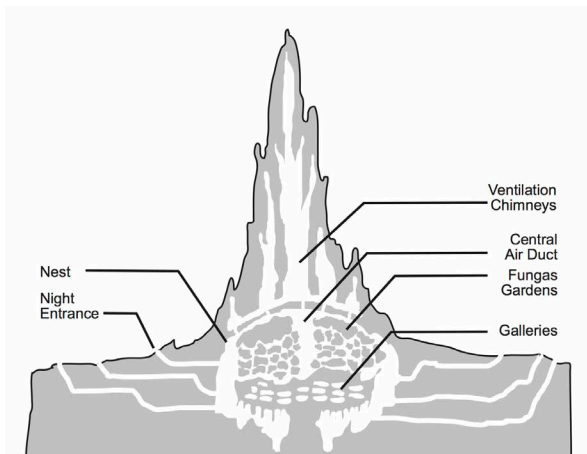
FIGURE 6.7 Intrinsic production

FIGURE 6.8 Extrinsic production

§ 6.4   Discussion

The longterm danger of the quest for legibility, beyond the boredom of formularized urban design, is that […] we seek to build the legible city out of a kit of parts – paths, nodes, landmarks, districts and edges – while forgetting that they are the emergent wholes. (Dovey and Pafka, 2015, page 4)

In recent decades, urban scholarship has increasingly focused upon the social and relational forces that underlie and contribute to the production of space. Meanwhile, less attention has been placed

upon how the *material* armature of the city is enmeshed with these forces: reinforcing or resisting them. If politics, culture, and economics are relevant urban issues to consider at the social level, can we not also contemplate constraints or affordances operating at the physical level?

Dovey et al recently advocated to join the *'sciences of complexity and adaptation to the social theory framework of assemblage thinking with its focus on the productive flows, synergies and alliances between things rather than things in themselves'* (2015, page 9). By considering the dynamics of CAS, this paper re-conceptualizes how *things* do matter – but matter insofar as they help enable the flows, synergies and alliances that Dovey cites. Here, certain built things - without being deterministic - enter into *imbricated* relationships with human agents by affording 'potential actions' (Leonardi, 2011). They thereby *'act as a provisory platform that facilitates/allows or hinders/forbids participation in urban action'* (Kashef, 2009, page 93).
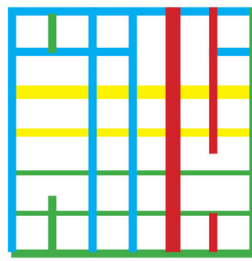
This paper sets out a framework that might be used to analyse how the formal substance of the city engenders or thwarts the unfolding of complex dynamics [Figure 6.9]. It provides an introduction to the rationale behind why such a framework might be beneficial, introduces a framework that employs intuitive categories (through the appropriation of Lynch), and provides illustrative examples of how this framework might illuminate various performative aspects of the built environment. That said, the framework is both preliminary and tentative. It also operates within set limits, engaging only with the study of urban complexity insofar as it pertains to processes that are activated or enabled in conjunction with the *material* armature of the city – the built fabric. Focusing on the built environment alone clearly precludes many other aspects of complexity that are critical in generating the city. Nonetheless, considering urban form from a CAS perspective may well produces insights about an important layer of complexity that permeates our cities.

Clearly, more research is needed to understand the productive capacity of this framework. Accordingly, the author has begun working with students to develop design strategies that use concepts from this framework not only as a means to undertake urban analysis, but also to generate new design interventions – ones that are open-ended, adaptable and resilient. Early results of this work show great promise.

This research can also benefit through an engagement with other contemporary urban practices that explore how the built environment may 'learn' over time. Tactical Urbanism, Pop-up Urbanism and other grass-root Insurgent Strategies employing 'Light, Quick and Cheap' (LQC) tactics emphasize incremental and provisional testing that are capable of responding to feedback (Silva, 2016). In a similar vein, Landscape Urbanism with its interest in 'staging uncertainties' and 'offering affordances' creates urban space in much more fluid and experimental ways that relies on activating potential futures and seeing how these unfold (Durack, 2001; Waldheim, 2006). Both approaches are well positioned to embrace a CAS ontology, but to date little work has fleshed out correspondences with CAS in ways that move beyond loose metaphor. While space does not permit these relationships to be expanded upon here, current research by the author is working to illuminate these connections.

CELLS/AGENTS:
Is the scale/malleability of the urban grain conducive to iteratively exploring multiple program manifestations?

PATHS/NETWORKS:
Are flows uninterrupted, and are there flows of different types, intensities, redundancies? Is the network that supports flows responsive and adaptive?

EDGES/INFORMATION:
Is the viability of use/program made transparent through signals in the environment? How strong/reliable are the signals?

HUBS/ATTRACTORS:
Are there neighborhood areas where similar flows can coalesce into nodes? Are there district level areas where diverse flows can merge as landmarks?

DISTRICTS/EMERGENCE:
Is the emergence of functionally synergistic or complementary program elements manifested?

FIGURE 6.9 Illustration of CAS aspects

7 The Grand Bazaar in Istanbul: The Emergent Unfolding of a Complex Adaptive System

Abstract

The Grand Bazaar in Istanbul offers an example of a physical environment containing specific districts that have emerged over time. This paper theorizes that the Grand Bazaar exhibits the characteristics of a Complex Adaptive System. Then, it considers specific urban elements found in the Bazaar, in light of complexity theory, to see how these facilitate processes that lead to the emergence of contiguous districts. This study repurposes Kevin Lynch's categorization of urban elements to provide a useful framework for discussing complexity theory. This research is further informed by economic analysis derived from Evolutionary Economic Geography, which examines the emergence of business clusters.

Keywords

Grand Bazaar, self-organization, Complex Adaptive Systems Theory, emergence, Evolutionary Economic Geography, Kevin Lynch.

Note

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Preamble

The year is 2006. It is my first day in Istanbul with my mother, and we have just wandered from our hotel, the Taş Konak, after settling in from our afternoon flight. It is early evening, and we are strolling the streets of the city. We amble past merchants in the Bazaar, each calling to us – 'Come in! Just to look not to buy', 'Hello/bonjour where are you from? American? France?' and 'Come ladies! Sit and drink tea with me'. We thread our way along streets, drifting deeper into the market, when yet another merchant startles us as he smiles and states, 'Hello, Canadian mother and daughter from Taş Konak! Please come in to take a look.'

Who is this man? We have never seen him before, nor he us. But he knows who we are, the nature of our relationship, and where we are from. In a city of more than 10 million people, amid a throng of tourists, and within a few hours of landing, our presence has been noted, transmitted and successfully deployed to draw us into this particular shop, with this particular merchandise.

Later, our host will summon tea. Tulip-shaped glasses appear, like magic, carried on a silver tray by a young boy who quickly disappears. The tea serves as part ritual, part sales pitch – connecting with time honoured traditions of hospitality to strangers, while serving to extend our stay in the shop as our host describes the wonders of his carpets.

This dance of knowledge, flow and traditions that extends throughout the labyrinth of the Bazaar is part of a weave of complex relations that unfolds in and through the urban fabric. My mother and I enter into this weave and our flow is quickly directed and modified by complex forces on the ground, bringing us to this particular juncture of site, meaning and culture.

§ 7.1 Part 1: Historical Stability - Formation of Districts within the Grand Bazaar

The Bazaar was neither simply a Tower of Babel nor a picturesque scene: it was a complex reality that would achieve a harmonious equilibrium (Mortan and Kücükerman, 2009, page 89).

Established in 1454 under Ottoman Sultan Mehmet II (1451-81), the Grand Bazaar has for centuries served as Istanbul's commercial centre and continues to operate as an important civic hub. Initially, the bazaar's site was chosen in accordance with settlement patterns of the Byzantine city in an area already established as an important centre for trade (Peker, 2010). The location of the Istanbul *Bedesten*, the first section of the bazaar (adjacent to the Imperial Road, now *Divan Yolu),* thus maintained old patterns of trade but altered the mode through which trade was administered and taxed. Under the Ottomans, the bazaar began to operate under the auspices of the *vakıf* (pious foundation) system, whereby the *vakıf* facilitated the construction of the bazaar through funds drawn from charitable endowments and then went on to collect rents from tradesmen. These pious foundations, *'were created in the towns and cities of the Ottoman Empire in early times by the sultans, their mothers, and high-ranking state officials. Being financially as well as administratively autonomous, these foundations were responsible for the construction of the cultural and commercial complexes in conquered cities'* (Yildirim, 2008, page 86).

Funds generated from rents were in turn used to support the work of the pious foundations, including the bazaar's upkeep, financial support for schools, hospices and soup kitchens, and maintenance of the city's mosques. The *Cevahir Bedesten* (jewellery market), the oldest portion of the bazaar, was established to generate financial resources for the *Ayasofya* Mosque. The bazaar was thereby part of a broader civic economic ecology that supported educational, religious and commercial components of city life (Inalcik, 1969).

Various guilds designated streets around the *bedesten* as sites where merchants could sell their wares. Over time, these commercial streets expanded in response to the demands of a growing population. *Han*s (business inn) were built to serve as central depositories for shipments intended for a particular craft or guild. The bazaar was thus comprised of guild streets (zoned by trade), *han*s that encircled the periphery and served as central depots, and *bedesten*s used as storehouses and vaults for precious items.

While maintaining this general framework, the bazaar's physical structure nonetheless underwent various expansions and transformations over the centuries. Fires and earthquakes played a role in this evolution, since sections were frequently destroyed and rebuilt. Nonetheless, the same general structure was preserved. In its present incarnation, the covered market dates back to 1750. However, the 1894 earthquake reduced the market's scale: following that event, certain streets (including the book market) formerly enclosed within the bazaar, were left outside its boundaries. This reduced footprint is indicative of the bazaar's declining popularity, as new commercial enterprises – following European models – opened on Rue de Pera (today *İstiklal Caddesi*). The last significant rebuilding

occurred after a fire in the 1950s; but despite extensive damage, reconstruction preserved the original built morphology.

Today, the bazaar primarily serves the tourist market. In approximately 75 acres it contains roughly 4,000 shops and 61 streets.[31] Within this area are an array of supporting amenities such as *hans*, cafés, restaurants, currency exchanges, tea houses, and mosques (Tokatli and Boyaci, 1999). Streets bordering the bazaar form a contiguous open-air market [Figure 7.1]. The boundaries between these interior and exterior streets are at times clearly demarcated and at other times blurred: some streets of the bazaar lie within the original gates but remain uncovered, while in other cases streets, now covered, lie outside the bazaar's walls.
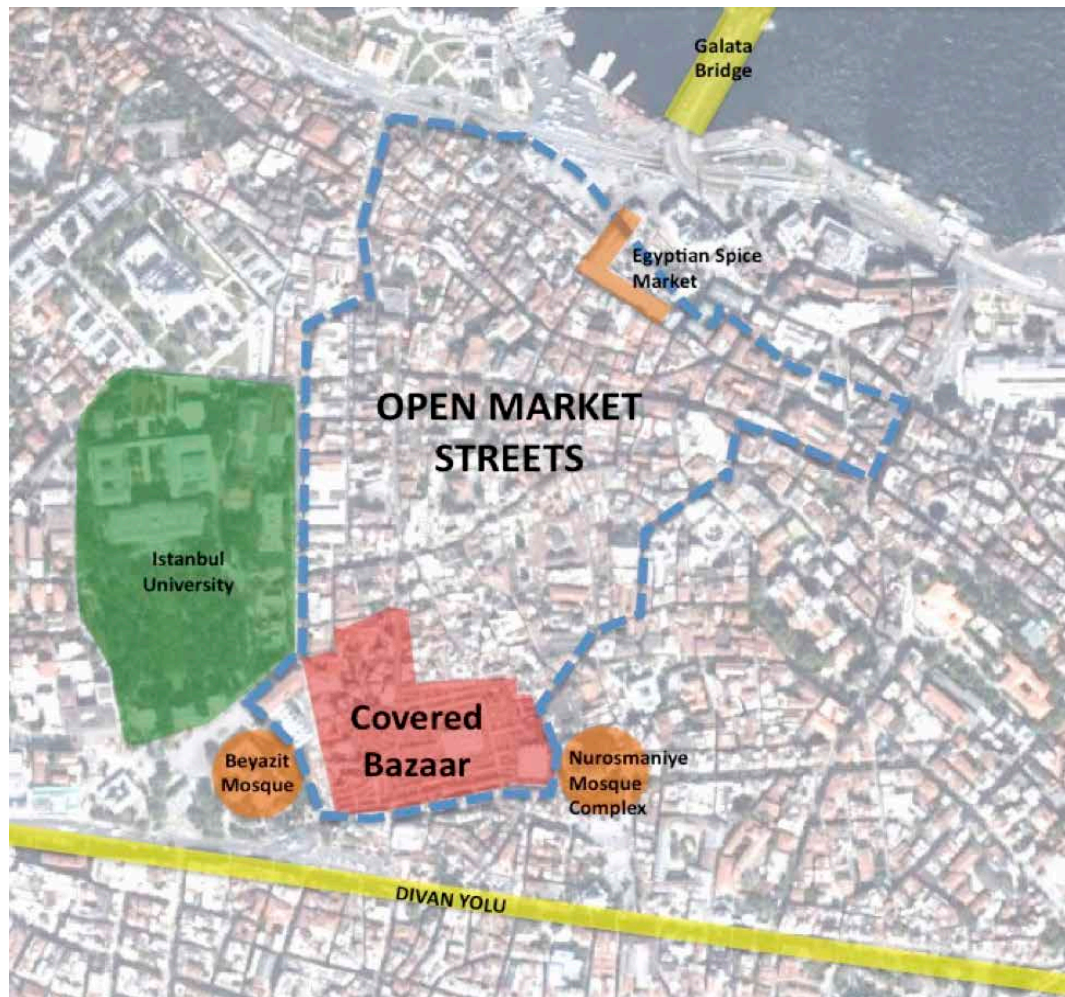

FIGURE 7.1 Greater Context, Istanbul.

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31   The precise number of shops in the Bazaar cannot be quantified as this continuously changes when stores subdivide or amalgamate.

For most of the bazaar's history, the guild system ensured that it functioned as both a cultural and economic entity. Craftsmen appointed guild leaders from their membership, and these leaders would in turn guarantee members a sound living. Guilds purchased and equitably distributed raw materials to their members, set ceiling prices on goods, imposed quality standards, determined the number of craftsmen permitted to practice a particular trade, and standardized shop dimensions (Inalcik, 1969). These measures protected consumers from shoddy goods and high prices as well as ensuring a stable market for merchants. In this context, competition or 'profiteering' was seen as a threat to the system (Inalcik, 1969). Instead, guilds aligned themselves with faith-based associations and worked to foster honour, tradition and brotherhood amongst their members (Lewis, 1937). Competition and innovation were discouraged in an effort to preserve customs and stability (Yi, 2004).

The location for each type of merchandise was established in the early days of the market. This occurred through a gradual process whereby temporary shops of traveling merchants would gradually evolve into permanent locations. Thus, *'the itinerant vendors of retail goods opened shops and were sedentarized [...] when one peddler's business flourished, others came and built shops next to his. The number of shops increased, [whereby] a cluster would occur of shops arranged according to the kind of goods sold'* (Mortan and Kücükerman, 2009) .

*Han*s were established to serve as central depots where goods were stored and then deployed to craftsmen within a particular district. This concentration of similar products reduced transportation and search costs for consumers and distributors (Arafat, 2012). The guilds, along with the pious foundations, structured and stabilized these locations by instituting a *'pre-capitalist form of agglomeration'* (Modarres, 2012, page 251). But the number of merchants in a guild and the size of the district they occupied varied *'according to the vicissitudes of the market'* (Yildirim, 2008, page 82). While it has generally been assumed that guilds exercised a high level of control over membership, quality and price restrictions, Eunjeong Yi observes that, *'guilds apparently did not attempt to impose strict regulations on people coming into their trade or leaving it [...] shops changed hands freely and with little signs of involvement on the part of guild authorities'* (Yi, 2004, page 53). Yi notes that as the city's population grew, the infrastructure provided for specific trades proved inadequate and merchants moved outside the confines of their initial district. The location of each guild in Istanbul therefore did not remain confined to specific streets or quarters and *'spatial concentration was not a binding principle'* (Yi, 2004, page 25).

In the eighteenth century, Ottoman officials introduced the *gedik* system (complex term variously indicating tenancy rights or usufruct of transferrable property particular to a given craft) that licensed the number of craftsmen practicing a particular trade. However, as noted in the definition, these licenses were not tied to a particular location and were transferable in some circumstances (Yildirim, 2008, page 92). The impact of this system was twofold. First, when craftsmen lost their certificates, *'[they] sought to practice their crafts outside the area designated for their guilds.'* Second, *'the selling of gedik certificates enabled people with no artisan background to enter the guilds. Thus the gedik implied not only the spatial disintegration of the guild system but also significantly hampered its hierarchical workings in the long run'* (Yildirim, 2008, page 74). The guild system further eroded after 1865 when ceiling prices were abolished (Mortan and Kücükerman, 2009). Thereafter, a massive influx of cheap imports from the West continued to weaken and de-stabilize the equilibrium the guilds had sought to maintain. In the absence of external control (and with the final dissolution of the guilds in the early 1900s) shopkeepers in the Grand Bazaar gained autonomy over what they could sell and where they could sell it.

Despite this autonomy, product selections continued to converge, such that discernible districts of similar goods emerged. Two maps of the Grand Bazaar [32] depict its spatial regions at different times, exemplifying both the changing character of the bazaar and the persistence of coherent districts despite forces of change.[33]

The first map [Figure 7.2a] depicts the bazaar in the 1960s. It includes districts of furniture producers, quilt-makers and scarf and towel manufacturers. The second map [Figure 7.2b], dated 2000, bears no trace of these goods, instead revealing the rise of denim-wear and souvenir shops. In this latter map, jewellers have expanded to form a continuous band along the south edge of the bazaar. Souvenir shops form a large swath that dominates the western block. A single arm of fabric shops stretches toward the market's northern boundaries, ultimately connecting with fabric-dealers situated outside the confines of the bazaar. Antiquity dealers have relocated entirely, leaving a small zone in the southeast sector to occupy a new sector encircling the old *bedesten*. Sellers of leather goods are distributed in amorphous clumps. These concentrated distributions of particular goods are all emergent districts not planned by the individual merchants. But how have contiguous districts emerged in the absence of any guild or centralized control?

The bazaar captures imprints of spatial patterns and connections that have coalesced over time. This article examines how features of the urban fabric shape and modify these forces and flows in ways that support the bazaar's evolutionary capacity.[34] In what follows, I will consider Complex Adaptive Systems (CAS) theory as a means of informing our understanding of present-day districts in the bazaar. The analysis will demonstrate how these districts might be explained through the phenomenon of *emergence*, a feature of CAS that arises from the uncoordinated interactions of many independent agents. In addition, I employ research from Evolutionary Economic Geography (EEG), a branch of economics that draws from complexity theory, to supply complementary insights into the mechanisms through which spatial agglomerations occur (Boschma and Frenken, 2005, 2011). The following section will introduce CAS theory before considering the bazaar through this lens.

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32   Both these maps are reproduced from Köroglu (2010), originally from other sources.

33   For further discussion of this phenomena of shifting functions in Islamic Bazaars, see also: (Arafat, 2012; Madoeuf and Snider, 2012)

34   The author uses a combination of information gathering methods, including a review of historical literature and academic articles (listed in citations) pertaining to the Bazaar's economic, social and cultural aspects. The author conducted ethnographic observations (between 1997-2011), remote interviews with select Bazaar Merchants in 2013, and field research and interviews in 2014, (with representatives from the markets for leather, jewellery, antiques, custom art, and carpets). Quotes from merchants are derived from either the author's formal questionnaires or cited sources. During face-to-face interviews conducted in 2014 (approximately 25 interviews with both merchants that had been in the bazaar for generations as well as relative newcomers) no verbatim records were made. The decision not to record notes directly facilitated a less formalized discussion, which note taking or recording may have hindered. The author recorded the essence of the interviews as faithfully as possible following each discussion. In addition, the author attempted to have each merchant steer the content of these discussions, in order not to bias findings.

Legend
- Carpet Dealers
- Furniture Dealers
- Quilt/ Leather Makers
- Secondhand Clothes
- Leather Dealers
- Slipper Makers
- Towel Miller
- Jewellers
- Antiquity Dealers
- Shoe Makers
- Leather Clothes Makers
- Silverware Dealers

A   Bazaar Districts, 1960.

Legend
- Carpet Dealers
- Jewellers
- Fabric
- Souvenirs
- Leather Dealers
- Copper Dealers
- Silver Dealers
- Antiquity Dealers
- Denimwear Dealers
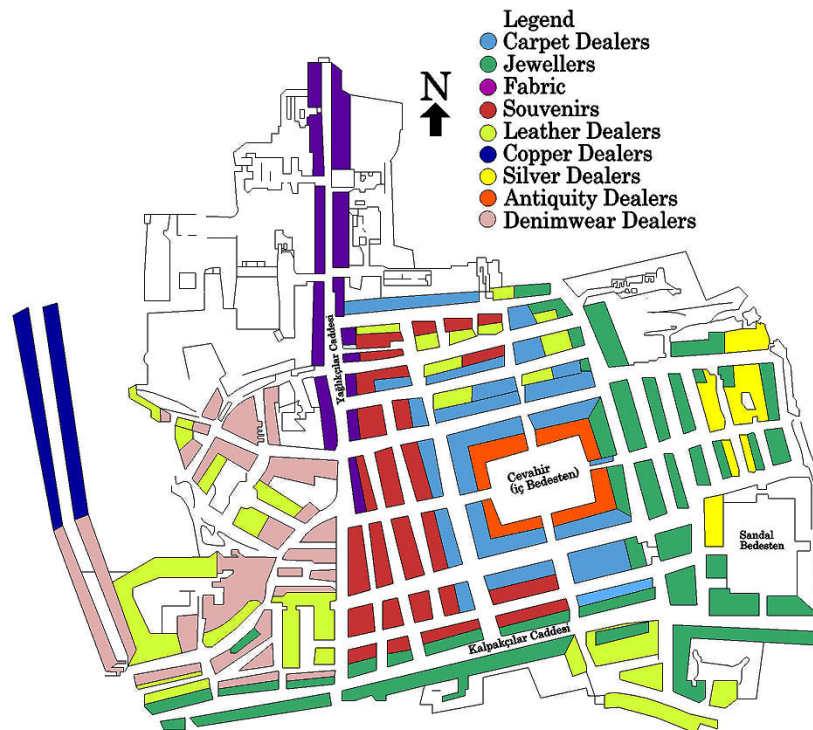
B   Bazaar Districts, 2000.

FIGURE 7.2 Comparison of Bazaar Districts (redrawn after Nebahat Tokatlı and Yonca Boyacı, 'The Changing Morphology of Commercial Activity in Istanbul', Cities 16, no. 3 (1999)

Part 2: Properties of Complex Adaptive Systems

The valuable city is not an ordered one, but one that can be ordered – a complexity whose pattern unfolds the more one experiences it. (Lynch, 1984, page 252)

A wide array of distributed interacting structures – ants in a colony, websites on the internet, traffic on a street network – can be identified as Complex Adaptive Systems (CAS) (Holland, 1995). CAS are *Complex*, in the technical sense that these systems are non-linear. Minor differences in initial conditions can lead to wildly divergent trajectories for the system's end state. They are *Adaptive,* evolving over time and retaining useful characteristics, and they are *Systems,* composed of networks of interacting parts. Finally, they possess *Emergent* features: global properties that are irreducible to the additive characteristics of the individual parts. CAS theory, though originating within the physical sciences, can be used to analyse a wide array of systems (For a more detailed review, see for example: Bonabeau et al., 1995; Heylighen, 1997; Kauffman, 1993; Wolf and Holvoet, 2004).

CAS' are composed of basic independent units, termed 'agents'. Agents in complex systems evolve according to general Darwinian mechanisms of variation, selection and retention. The nature of an agent varies depending on the system under analysis. Agents might be ants in a colony, sites on the Internet or stocks on the market. Agents mutate and adapt their behaviour, testing strategies that might draw resources their way. They then evaluate and adapt their actions depending upon whether feedback from this new behaviour indicates that they have moved closer to, or farther from, a particular goal.

Scientists generally describe this process of testing strategies as exploring a 'fitness landscape' – the agent's resource environment. This landscape is not static. Rather, it appears shifting and uneven, modified by outside disturbances (perturbations), the presence or absence of resources and the interactions of agents inside it. Agents can explore the landscape in various ways: by refining existing strategies (climbing a fitness peak) or testing novel strategies (jumping to a new peak). Agents guide each other in exploring the fitness landscape through receiving and deploying signals called 'tags' (or stigmergic signals). Tags leave traces of strategies that are perceptible to other agents in the environment, thereby informing subsequent behaviour (Heylighen, 2006, page 7). Ants, for example, deploy pheromones to tag their environment thus guiding other ants toward food sources. Agents in CAS work simultaneously to explore the broadest possible range of fitness strategies. But these independent agents also exhibit a natural tendency to coalesce into larger aggregates, reducing the transaction costs of moving resources within the system (Simon, 1962, page 468). These emergent clusters (or 'patches') exploit distinct forms of energy resources, while transference between patches allows resources to effectively propagate throughout the system as a whole (Kauffman, 1996).

While CAS theory focuses on the attributes of agents, network theory examines the topology of the flows that are transferred between agents. Resource flows (such as water, nutrients, dollars, etc.) fuel a CAS. The architecture of these flows evolves from the interactions of agents, but once in place, it begins to constrain subsequent topological features of the system. For example, the networked links of the Internet form an architecture that has emerged over time, but the dominance of particular sites (like Wikipedia) subsequently reinforces traffic flows to specific nodes. Networks thereby evolve into hierarchies of loosely and highly connected nodes.

This hierarchical arrangement of nodes follows a regular mathematical distribution, which is described by power laws. Examples of power law distributions found in CAS include: frequented sites on the Internet; rank distribution sizes of cities; and cited articles in academic journals. The presence

of power law phenomena appears to be a natural attribute of systems that exhibit both growth and preferential attachment (Barabási and Albert, 1999). This ubiquitous structure allows for shortcuts or 'small worlds' that propagate flows. The capacity of a network to efficiently propagate resource flows and spur novel interactions is affected by structural aspects of network topology. Thus, the number and kinds of linkages are important, as well as the presence of a hierarchy of nodes that directs flows and maintains system stability (Barabási and Albert, 1999). Distributed hierarchies of nodes serve other purposes. At the local level, junctions connect similar agents (an internet chat group on physics, for example). Higher up the hierarchical chain, major hubs bridge communities and disperse knowledge between groups (Google News, for example).

Finally, CAS systems can display emergent properties. These are features that, while clearly discernible, cannot be attributed directly to any of the agents that make up the system, nor are they the direct additive result of agent attributes. Examples of emergent phenomena include tornadoes, fish schools and stock market crashes.

§ 7.3   Part 3: Applying CAS to Urban Phenomena

The above features of CAS apply to any system domain (physical, chemical, biological, etc.), but are operationalized through distinct material or physical *carriers* specific to the system in question. In my analysis of the Grand Bazaar of Istanbul, I am interested in considering the physical features of the urban environment that support the bazaar and behave as a CAS. I therefore would like to turn towards identifying what aspects of the urban fabric might serve as enabling carriers of complex processes.

Kevin Lynch's (1960) framework for analysing cities (*paths, landmarks, districts, edges and nodes)* supplies a well-established analytical system that differentiates between key urban elements.[35] That said, Lynch's urban properties are generally viewed as 'physical' artefacts, where 'good city form' is seen as deriving from a well composed ordering of these elements. I wish to consider how this classification methodology can instead be repurposed to examine 'functional' attributes: where certain physical artefacts are important, not because of what they look like, but because of the behaviours they perform or enable. I employ Lynch's classification system as a means of identifying properties of CAS, because his features are familiar and intuitive as a starting point and not because I am analysing the Bazaar according to Lynch's rubric.

The table below **[Figure 7.1],** illustrates the links between Lynch's original formal designations, how these apply to physical features of the Grand Bazaar and how these physical features can be reinterpreted as functional features. These functions are then related to CAS properties. In order to make Lynch's system correspond to CAS properties, I have incorporated an additional feature – cell – to the original set. With this analytical framework in place, the next section considers how the urban fabric of the bazaar facilitates CAS processes.

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35   I should clarify that my intention here is not to provide a 'Lynchian' analysis of the Bazaar, but rather to employ Lynch's urban categories as a way to discuss the Bazaar as a CAS.

LYNCH'S SYSTEM (MODIFIED_		
Physical Features	**Functional Role in CAS**	**Ecosystem Examples**
A. Cells: Typical Grain of Urban Fabric (shops/homes/etc.).	Parallel agents working to maximize resource use.	Species (birds, insects, mammals).
B. Paths Street Networks (carrying tourists, information, money, merchandise, etc.).	Network links facilitating flows of resources, information and energy entering the system and connecting agents across space.	Channels of energy sources flowing through an environment (streams, sun-paths, soil nutrients, foraging trails).
C. Hubs (Landmaks and Nodes) Gathering places (shop doorways, fountains, mosques, *hans*, coffee-houses, tea-house, currency exchanges).	Juntions within networks where resource flows, either maintain existing memories of useful flows, or test new sub-routines that transform flows into more useful forms.	Food/fuel source sites (ponds, nutrient pools, fruiting plants, etc.) or storage stashes and congregation sites (nests, ant hills, dens, etc.).
D. Edges [1] Storefronts and displays.	Tags signifying agent competencies, steering resources towards agents that can best process them. Also broadcasting successful and unsuccessful agent strategies for resource processing.	Patches of species inhabiting a particular niche (schools of fish, flocks of birds).
E. Districts Zones of similar products (leather, denim, fabric, etc.).	Aggregations of co-evolved agents that efficiently circulate resources.	Patches of species inhabiting a parcular niche (schools of fish, flocks of birds).

TABLE 7.1 Adopting a Lynchian tool-kit for analysing CAS processes;
Note [1]: In Lynch's original framework, edges are specified as being the boundary conditions of districts. However, the term has subsequently been employed by designers to consider characteristics of street facades that border paths. It is this usage that proves most useful for this discussion.

§ 7.4 **Part 4: Modern Flux -The Bazaar as a Complex Adaptive System**

A settlement is a valued arrangement, consciously changed and stabilized. Its elements are connected through an immense and intricate network, which can be understood only as a series of overlapping local systems, never rigidly or instantaneously linked, and yet part of a fabric without edges. Each part has a history and a context, and that history and context shifts as we move from part to part (Lynch, 1984, page 116).

A **Cells: Agents of CAS**

The grain or texture of the Grand Bazaar is comprised of the individual shops that define its fabric. When considering the Grand Bazaar as a complex system, these shops perform as cells or *agents*. Each cell is one of a series of parallel entities that form the base site of agency within this particular complex adaptive system (whereas an ant is an agent in a colony, for example). In CAS theory, the term 'agent' has a different usage where it is used to identify the base components of the system under study. This usage should be distinguished from 'agency', which implies volition. No volition is being ascribed to the inanimate building blocks of urban form and it is meaningless to speak of a shop having 'agency'. Nonetheless, a shopkeeper's agency is constrained by the material possibilities of the shop he or she occupies. Thus, a cobbler operating in a space of five square meters cannot repurpose his space to run a hotel. Thus, cells affect agency, not because these cells are independent of human agents that interact with them, but to the extent that material artefacts provide an interface that mediates and structures human agency. Shops mediate between two types of actors in the bazaar with different goals: merchants and shoppers. These goals are negotiated at the site of the shop, where spatial

characteristics assume agency (in the way that stock prices, within the complex system of the market, act as an interface between buyers and sellers, but do not have agency *per se*). I wish to examine how spatial characteristics of these cells affect the kinds of physical patterns that are possible within the bazaar.

John Holland highlights the importance of the flexible nature of agents within CAS, emphasizing that having the smallest possible functional scale that can be aggregated into larger units provides the greatest adaptability within these systems (Holland, 1995). In the bazaar, the small and flexible nature of cells supports variation. Cells span one structural bay of the market, generally a distance of ten feet (though this varies from street to street). Typically, a cell encloses an area of 100 square feet that is programmed by owners, in accordance with their needs and their merchandise. Businesses normally operate within a single cell, but if successful, they may appropriate additional cells located in nearby storefronts or streets [Figure 4]. In some cases, shops extend into neighbouring cells, particularly if the merchandise is larger in scale (for example, carpet stores). In these cases, merchants occasionally create openings between cells [Figure 5] that are covered over if shops revert to separate ownership. In instances where products are small, cells can also be divided in half to offset high rents. This occurs in some jewellery sections and at currency exchanges **[Figure 7.3, images 1 - 4]**. Similarly, corner cells are often bisected to create two triangular stores. These operate independently, facing adjacent streets at right angles.

1   *Image showing neighbouring cells/shops*

2   *Two independent cells joined to form one shop*
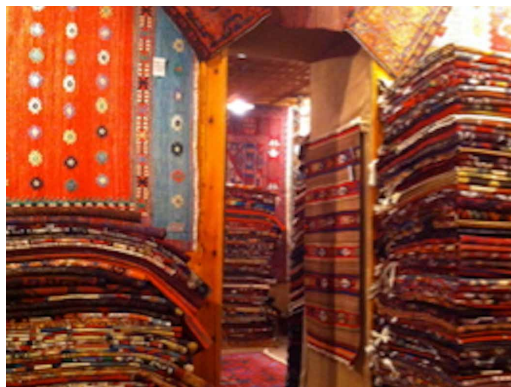
3   *Opening passage made in wall between cells*

4   *Cells subdivided to form narrower shops*

FIGURE 7.3 Various ways in which 'cells'are occupied and partitioned

The bazaar cell's small scale permits new markets, goods and districts to be tested with relatively minimal investment. Strategies are then refined or abandoned. This adaptability, along with the high number of possible iterations (4,000), provides inherent flexibility and the benefits of massive parallelism - accelerating evolutionary optimization. Although a great many of these variant strategies may fail, successful ones will have opportunities to replicate through expansion (growing into additional cells) or the reproduction of techniques (surrounding cells mutating to mimic success). Evolution occurs quickly because variant cells are not only sequential, but also parallel. The range of independently operated shops enables swifter adjustments to merchandise selections, locational choices and marketing tactics. Owners gain immediate feedback on their tactics such that, according to evolutionary economists, *'differential profits leading to differential growth rates render fitter routines to become more dominant'* (Boschma and Frenken, 2005, page 278).

These processes are echoed in the shopkeepers' personal narratives. One owner, discussing transitioning from traditional carpet sales to custom patchwork rugs, explains: *'we started really small and in a way, very amateurish, but we received very positive feedback and became a name for patchwork'* (interview with Memet Güreli, 2013). Gradually, he converted his stock to fill this niche and opened a second location. Another source describes how an owner had, *'[begun] an internship here when he was just 12 years old and after years of training he operates three stores, all different from each other. His principal store, on the main street of the bazaar, turns merchandise 13 times a year allowing [him] to infuse new concepts and products'* (Weir, 2012). Another owner I interviewed described his great-grandfather as a watchmaker in the bazaar. In the l950s his grandfather moved to a new location, giving up the watch-making business to sell carpets and decorative animal skins. His father transitioned to selling leather artwork and the son, a fourth-generation owner, now sells leatherwear.

Evolutionary Economic Geography describes this process of exploring products and concepts as a testing of rules whereby *'an agent originates, adopts, adapts and retains a novel generic rule'* (Dopfer et al., 2004, page 269). Spin-off firms inherit successful rules from parent companies, leading to competitive advantages within the marketplace. Agents test survival strategies in parallel, such that 'each agent interacts with a subset of other agents, and each agent carries only a subset of all economic rules' (Dopfer et al., 2004, page 269). Good rules propagate across the system:

An agent explores a new rule and its capabilities. This is a phase of learning and experimentation for a single agent, but as other agents also adopt the same rule, adoption, in turn, drives adaptation. This process of evolution re-structures the market and the organizational environment. (Dopfer et al., 2004, page 272)

This step-by-step succession process takes place in the bazaar, where unsuccessful enterprises fail, shops transition to new owners, (selling the same or different goods) and *'market competition acts as a selection device causing 'smart' fit routines to diffuse and 'stupid' unfit routines to disappear'* (Boschma and Frenken, 2005, page 278). Successful enterprises begin dominating and expanding in the bazaar, creating contiguous territories. The experiences of my interviewees illustrate this point. One subject, a newcomer to the bazaar, opened a carpet business in a shop that previously sold textiles. After successfully establishing this business he acquired two additional shops (only one of which previously sold carpets) that were closely situated to his first shop. A cluster of carpet stores began to emerge in a process that now attracts subsequent entrants into the market.

In addition to promoting ease of variation, the bazaar's small scale promotes long-term stability once successful strategies are discovered. Most shops consist of one to three owners and are family-run (Kamrava, 2004). Many have been in the same hands for generations, with successful routines

remaining intact as they are passed down from one owner to the next. Resources (financial or personnel) from extended family networks can be drawn upon in times of need (Kamrava, 2004). Family members provide supplemental staff during busy periods or can mind the store when business is slow, allowing owners to pursue side ventures so as to accumulate capital (such as travel to acquire goods or sales trips to other markets). The shop's small scale means that localized family resources are sufficient to mediate fluctuations.

This independent, small-ownership model thereby helps stabilize successful routines. It also means that the shop's success is linked to the character and reputation of the shopkeeper. One interviewee mentioned that after working in the bazaar for more than fifty years, he was able to leverage his personal reputation to obtain the necessary financing to purchase his rented shop. He explains: '*If your name has received the personal-credit of the others in your social and business circles, then money plays a secondary role, even if you don't have it all at that particular time*'. The transition from renting to owning further stabilized his enterprise, consolidating the shop's place in the urban fabric. But this stability could not have been achieved without his positive personal reputation. The shop owner elaborates:

While the new banking laws in Turkey require a financial statement, being tradesman in the Grand Bazaar is enough of a statement for a bank. By comparison with the rest of the country, it is a very simple matter to conduct a credit check in the Bazaar because everyone knows each other and, as a result, the failing on credit payments, quite high nationwide, is almost unheard of here. (Mortan and Kücükerman, 2009, page 227)

B   PATHS: Resource Carriers of CAS Networks

The bazaar sits at the crossroads of historically significant routes, channelling a high volume of resources inside its walls. Street networks, comprised of both shorter, local pathways as well as longer routes, serve as carriers of human, material, monetary and informational flows. Gateways into the bazaar gather denser flows from the port, the tourist district, the mosque and nearby Istanbul University. Inside the bazaar, streets form a tightly-woven grid that provides many potential routes between destinations. This variety generates shortcuts, cycling resources more effectively among agents and prompting synergetic connections. The physical topology of the Grand Bazaar's street network is intrinsically elastic, having the capacity to respond differentially to changing structures and hierarchies of flows. According to network theory, this high degree of redundancy in resource flows allows the network to auto-catalyse. Flows shift directions and densities, establishing new hierarchies, hubs and districts. Thus, the original *bedesten*, once a major hub of the bazaar, has diminished in importance. Flow patterns have adjusted accordingly.

The bazaar's longest streets are also generally the widest, and these avenues generate the market's thickest flows. Streets that are centrally located draw higher volumes of traffic, while peripheral zones remain more private. The scale of streets corresponds to traffic flows. Major gateways from *Nurosmaniye* Mosque [Figure 7] direct high volumes of traffic into the bazaar, where rents are most expensive. Entries from the west are narrower, and shops in this area sell lower-priced goods [Figure. 8]. In addition, spaces that are deeply embedded within the bazaar's spatial structure (the *hans* which are scattered around the peripheral sections), are accessed through a series of thresholds that act as boundaries, maintaining privacy. Entrances to these *hans* splinter off from main traffic routes, but, are recessed within several thresholds that inhibit tourists from entering. Additional barriers to movement appear within these *hans*, where older stairwells, leading to upper levels, discourage tourists. Rents are

less expensive in these secluded areas, and the second and third levels (used for storage and workshop space) are more private and removed from flows **[Figure 7.4, images 3-6].**

3   Nuruosmaniye Kapısı.

4   Bazaar Gateways: entry from the West,

5   Han Entry: leather District.

6   Road leading to Bazaar Gateway

FIGURE 7.4 Various Gateway Conditions

High variations of denser and sparser flows inside the bazaar result in a wide range of rental rates. This means that different occupants can appropriate niches according to available resources. The market's highest rents correspond to locations where flows are greatest and to the highest-priced targeted goods. Thus, the *Kalpakçılar* (the east/west artery from *Nurosmaniye* Mosque) draws not only tourists, but also specialized buyers who are focused on purchasing silver and gold. By contrast, the *Yağlıkçılar/ Sipahi* artery (the north/west route with the longest continuity) also attracts high tourist volume, but these visitors are not seeking a particular good. Here, souvenir shops appear in abundance, and goods on offer are far more heterogeneous than at other locations inside the bazaar.

While high volumes of flows are important for garnering customers, other strategies are relevant when flows become distilled into individuals searching for specific products. Visitors interested in carpets are more likely to gravitate to a zone (that is less frequented) if it signals a higher percentage of carpet shops. Merchants thus evaluate the trade-offs between situating themselves in the presence of general flows (attempting to capture a portion of them) and moving to more remote locations that draw targeted flows (bringing fewer general consumers, but more buyers who are interested in their particular product line). Tourists, looking for non-specialized products, create high volumes

of general flows, while thinner but more focused flows result from local or specialized users. These differences affect the character of each district. Streets that capture tourist flows are the bazaar's most heterogeneous, where shopkeepers try to entice tourists with an array of products. By contrast, in areas where flows are in the form of repeat customers, shops display greater specificity and contiguity. Flows on the streets north of the bazaar are produced mostly by locals, and these areas appear far more specialized, with contiguous districts emerging to capture these repeat flows [Figure 7.5].

Another strategy adopted by merchants who evaluate the trade-offs between choice locational streets and rental costs, is to maintain more than one location. In these cases, merchants occupy a small shop where higher traffic volumes exist, while also renting satellite shops on less expensive streets (or in *hans*). These satellite shops hold additional goods that can be quickly shuttled over to a customer at the main location. Here, the flow of goods supplants the flow of people, as merchants make their goods mobile.

FIGURE 7.5 Market Streets: shopping district north of Bazaar.
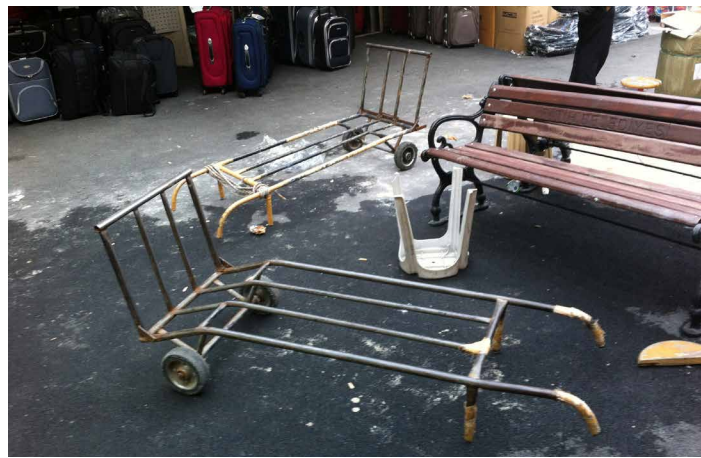
FIGURE 7.6 Market Streets: transport carts

This movement of goods is but one example as an abundance of material flows help catalyse the Grand Bazaar's functions. In addition, there are mechanisms that ensure these flows find their way to where they are most needed. For example, merchants employ cell phones to quickly access merchandise or personnel from other locations, or order tea to build social capital during a transaction. Porters quickly and efficiently navigate the streets, bringing goods, food or tea from one region to another. The flexible and agile qualities of human pulled carts (or on the backs of porters, though this is becoming less common) are used to transport material flows along the tight streets [Figure 7.6]. Touts direct tourists to goods, leading them from one district to another, or deliver information to merchants regarding potential customers. Flows of products entering and exiting the market interact with, and are altered by, these knowledge flows.

EEG characterizes flows as consisting of capital, labour and knowledge (Boschma and Frenken, 2006) In the presence of rich flows, ventures are apt to achieve greater success. This process results from:

(1) The mobility of human capital as the carrier of (often tacit) knowledge in these areas, (2) the transfer and feedback of information via dense (mainly informal) networks of local actors, reinforced by the techno-industrial specialization of the area, and (3) a common local culture of trust, based on shared practices and rules. (Boschma and Lambooy, 1999, page 417)

While gaining monetary flows is a key indicator of shop success, not all merchants regard money as the only 'fitness criteria' for their enterprise. Historically, profit was not a primary motive for shops (provided that enterprises supplied a livelihood). Carl Johan Charpentier, writing about the bazaar in the 1960s, tells of a dealer refusing to sell him a large quantity of carpets, since the transaction would deplete his stock and thereby limit future opportunities to conduct sales and foster social interactions (Charpentier, 1976). This theme remained prevalent among many shopkeepers with whom I spoke. Longer-term tenants or owners seemed to be more concerned with building their reputation and relationships with repeat customers than with maximizing profit or drawing in tourists. But these priorities are changing. One of the subjects I interviewed commented on the loss of social 'glue' that forges connections within the Grand Bazaar. He clarified:

I notice the lacking social attention and respect towards one another when I compare it with the recent past. We all come here for our 'bread-money' but that does not mean that we should be ignoring the vital importance of other values, which are beyond making money, that play the glue-role in our daily life.

Many shopkeepers expressed concern over the influx of cheap counterfeit goods in the bazaar. One employee of a scarf shop explained how he had previously sold fake leather bags at the same location. Officials fined his employers several times for selling counterfeit goods, resulting in them eventually opting to sell scarves as a less lucrative but 'safer' enterprise. These owners were newcomers to the bazaar (investors) who had no interest in traditional forms (or authenticity). Furthermore, the owners entrusted the shop to an employee, rather than appearing on site, unlike traditional stores where the proprietor or close family members are always present. Similarly, new enterprises selling Turkish Delight (*lokum*) are run by outsiders. Several of these *lokum* shops have opened on the street with the highest rental rates, departing from the traditions of that street. But these shop-owners are not present. They run numerous outside businesses and are able to absorb the risks associated with failure. These shops' prices are high but fixed, allowing the owners to hire younger employees who are unskilled and do not have family ties of trust to the owner (normally required when prices are negotiated in the owner's absence).

Another concern expressed by shopkeepers with whom I spoke pertained to the loss of specialized knowledge flows. Compared to the challenges of selling a quality carpet, antique or leather good, minimal knowledge is required to sell a scarf or counterfeit bag. The value ascribed to artisan knowledge has thus diminished as profit motives increase. In more traditional businesses, historical values and reputation are still important. Merchants rely on their reputation, through referrals, repeat customers or guidebooks, to gather flows to their businesses. By contrast, selling souvenirs requires less technical knowledge and turnover is higher, with innovation and profitability being the main drivers. Businesses face enormous pressures to attract tourist dollars to pay for rents, which results in more aggressive marketing, including commissions to guides and touts - agents that distort natural flows. These factors result in competing cultures in the bazaar; one focused on high turnover in popular goods, and the other seeking to maintain tradition and authenticity. As material flows in the bazaar shift to meet tourism demands or satisfy profit-driven outside investors, there is growing concern that traditional values will be displaced. Shopkeepers must navigate between conflicting desires to attract tourists or repeat customers (located in main flows or specialized zones), and whether to maintain a personal relationship to their product or shift their focus to high-turnover goods.

Today's shifting architectural composition of districts reflects these competing values, with merchants adjusting their locational preferences in response to flows that are either monetary or pertain to social capital. Those merchants seeking to retain cultural traditions tend to be removed from major

flows, since their reputations drive their businesses. They remain focused on a particular fitness peak. Alternately, where profit is the driving force, merchants change what they sell according to consumer trends, which results in higher turnover and swifter adaptations. Here, merchants are engaged in jumping between peaks, creating regions that display the greatest volatility and creativity.

C   HUBS: Intersections of CAS networks

Complex networks are characterized by different kinds of linkages where flows from various sources converge. These intersections or 'hubs' ground and orient certain kinds of behaviours. Flows intersecting at these hubs can be characterized according to the following parameters:

A   Tacit vs. Explicit
B   Global vs. Local.

Scale -		TACIT (casual flows) >>>>>	<<<<< (formalized flows) EXPLICIT
		exploring landscape of new fit peaks (serendipity/creativity)	climbing landscape of existing fit peaks (memory/protocols/infrastructure)
	GLOBAL:	Nodes - *Han* Courtyards - Bath-houses	Landmarks (Global Pipeline) - Mosques - *Bedesten* (historically) - University
	LOCAL:	Junctions (Local Buzz) - Doorways - Shopfronts - Coffee/Tea shops - Barbershops	Anchors - Central Washroom sites - Tea Distibution centres - Fountain/Ablution sites

TABLE 7.2 Flows intersecting at 'hubs' , indicating performative attributes

Table 7.2 references particular spaces but draws attention to their performative rather than physical attributes. Here, nodes can be regarded as physical junctures that support temporary, informal connections, but are accessible to a global range of flows. Junctions, while also characterized by the informal and local nature of the social relations they foster, tend to attract more localized flows. Both are 'third spaces' (Oldenburg, 1999), connecting individuals from diverse backgrounds and supporting serendipitous interactions that may lead to innovations. Similarly, EEG discusses the importance of 'local buzz' (Bathelt et al., 2004b), as providing tacit resources that promote interactions and prompt innovation:

Buzz consists of specific information and continuous updates of this information, intended and unanticipated learning processes in organized and accidental meetings. In this context, actors are not deliberately 'scanning' their environment in search of a specific piece of information but rather are surrounded by a concoction of rumours, impressions, recommendations, trade folklore and strategic information. (Gernot Grabher, quoted in Bathelt et al., 2004b, page 38)

In contrast, Landmarks are the physical manifestation of weaves of thick flows that are channelled through more formalized and codified connections: the 'sacred' versus the 'profane' spaces of the city (Eliade, 1987). They channel flows that transcend day-to-day activities and permit local networks to 'jump scales', connecting to flows that operate at higher hierarchical levels (Bathelt et al., 2004b). Landmarks play a role analogous to 'pipelines' in EEG, acting as conduits through which global information is fed to local districts. Anchors also help preserve routine behaviours, but at the local rather than global level. The presence of local anchors means that certain tasks can be reliably

outsourced, freeing agent resources to focus on discrete tasks. In the bazaar, this means that each shop does not need to provide services such as restrooms, refreshments or repair services. Instead, the work of providing these amenities can be delegated to other general service providers (located at anchor points) and accessed through the flow channels of the bazaar. Both landmarks and anchors ensure system resilience in moments of stress, preserving stable protocols and codifying reliable routines.

When exploring a fitness landscape, interactions that promote serendipitous encounters are most valuable during times of innovation or 'exploring a fitness landscape'. By contrast, interactions that maintain memory and protocols are critical when building upon success or 'climbing a fitness peak'. Certain kinds of hubs enable informal, tentative connections to be explored at little cost. Others foster the maintenance of stabilized, routine interactions, where functions can be outsourced with no inherent risk. The presence of a variety of hubs within the urban fabric permits actors to explore and maintain networks of trust, knowledge, reciprocity and social capital (Martin and Sunley, 2003). These networks then fuel shops, by gathering and dispersing information, material or economic flows.

Nodes that encouraged tacit flows, such as those that historically were found in *han*s, coffeehouses, and bathhouses, have largely disappeared from the bazaar. Landmarks that once supported formalized connections have also been marginalized. Today, during the Friday call to prayer, mosques lack sufficient space to house all participants. While the bazaar's mosque plays an important functional part, it lacks a strong physical presence [Figure 7.7]. Prayer thus occurs on the streets of the bazaar [Figure 7.8]. By contrast, mosques outside the bazaar are both functional and physical landmarks. The erosion of global Nodes and Landmarks might explain the lack of social 'glue' that is now missing from the bazaar, according to shop-owners. Many merchants with whom I spoke point to a cultural rift developing in the bazaar between relative newcomers and others who have been present for generations. Given the absence of common hubs to bridge these rifts, friction between communities may continue to grow.
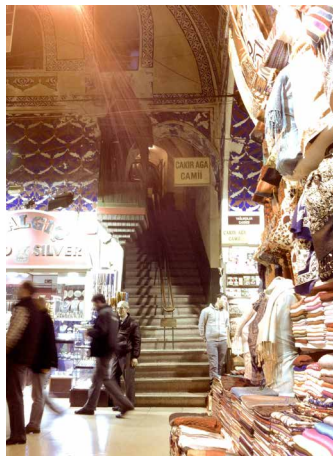

FIGURE 7.7 Çakır Ağa Mosque..

FIGURE 7.8 Friday Prayer: Yağlıkçılar Caddesi.

Despite these rifts, merchants in every section of the Bazaar spoke extremely positively about their immediate region. An oft-repeated comment was that their neighbourhood (an area encompassing approximately 50 shops) was 'like family'.[36] Those I interviewed knew each worker in their region and showed a preference for 'their' neighbourhood over others. While shopkeepers were familiar with individuals in their surroundings, they enjoyed close connections to only four to five of these workers, who often occupied different sectors. These connections seemed to derive from common values rather than commonalities of merchandise. Social connections appeared to develop at shifting junctions that occur on the streets, rather than in specialized locations. When business is slow, shopkeepers leave their shops but remain in close proximity to one another, engaging in conversation while keeping an eye on their store [Figure 7.9]. The entrances to shops thus serve as informal gathering places. When customers arrive, these tacit encounters shift to other storefronts. Merchants watch over the goods of other merchants, especially during prayer, when shops are vacated and merchandise is simply covered. One merchant I spoke with stated: *'there are ten eyes on the street, watching everything'*.

For the most part, social connections in the bazaar appear to be forged through street-side encounters. These practices differ from the past, when *han*s played an important role in creating ties. Historically, *han*s served as distribution depots, acting as important Nodes within the global context of tacit networks of flows. Distributors brought goods and news from afar, which were then disseminated through local guilds. *Han*s also served religious functions, by housing ablution fountains [Figure 7.10]. Today, *han*s have lost many of these functions, but still provide stable local infrastructure that supports surrounding businesses. They are local Anchors that sustain various district functions - restrooms, teahouses, barbershops and repair shops [Figure 7.11].

FIGURE 7.9 Temporary street junction: small table and chairs serving as a temporary node
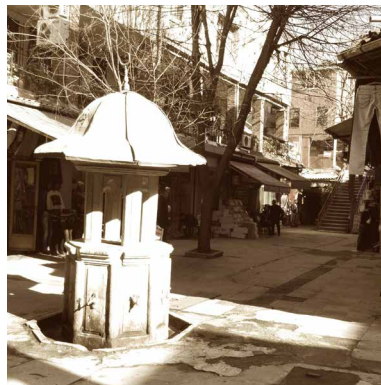
FIGURE 7.10 Ablution Fountain: Bodrum Han.

FIGURE 7.11 Hans today: Bodrum Han.

Some manufacturing persists in the *han*s [Figure 7.12], but this has diminished as larger-scale manufacturing workshops have relocated to peripheral regions. *Han*s on the streets surrounding the covered bazaar, while morphologically similar to those inside, operate differently. Whereas *han*s in the bazaar house heterogeneous shops on the main level, *han*s on the outside are more homogenous, storing and selling specific merchandise such as luggage, fabrics or silverware that is also sold in the immediate surroundings [Figure 7.13]. These *han*s continue to serve as major distribution points that mediate local and global flows.

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36   I should note that this particular phrase is a common idiom within Turkish culture and should be considered within this context (thanks to the anonymous reviewer for bringing this to my attention).

FIGURE 7.12 Artisan manufacturing in Han near Grand Bazaar: located on the second level of a Han adjacent to the Grand Bazaar.

FIGURE 7.13 Hans outside the Bazaar: (goods stored)

D   EDGES: Tags of CAS

Tags (or stigmergic signals) within a complex system operate as labels that broadcast, display, and manifest information regarding established strategies and competencies. These signals are perceptible to other agents and inform their subsequent behaviours. Within the context of the bazaar, tags take the form of each cell's street-frontage, where merchants display their goods.[37] Individual cells broadcast a range of signals, including the nature of work being undertaken (goods sold), popularity of merchandise (the number of visitors stopping), availability for casual interaction (whether doors are open or closed), marketing strategies (the format of items on display) and personal values (whether the space is vacated during prayer, or the nature of goods: craft versus counterfeit). Since individual street-frontages are narrow, a wide array of high-density information is available at a glance. Merchants stand or sit outside their shops, monitoring tourists and one another's business [Figures 7.14, 7.15]. Neighbours view what is displayed, purchased, by whom and in what quantities.

As competencies and demands shift, evidence of successful product lines become embedded in these tags. The street-front displays tag the shop's merchandise and competencies [Figures 7.15]. This information is immediate and reliable; uncluttered by 'noise' that interferes with signal fidelity. Merchants evaluate this information and use it to develop shortcuts in their respective evolutionary strategies. EEG discusses the advantages of these ambient signals whereby, '*firms benefit from their co-location through which they 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 et al., 2004b, page 36).

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37   Originally, Grand Bazaar shops were formed of shelf-like cabinets that were attended by the merchants. It was not until the 1894 Earthquake that this physical structure shifted. At that time the deeper shops we know today were opened up, with large window displays created that echoed the format being popularized in the Pera district.

FIGURE 7.14 Casual Street Monitoring
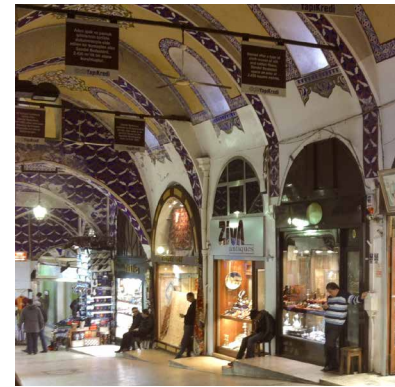
FIGURE 7.15 Tagging of Leather Goods

FIGURE 7.16 Testing of unique niche

Tags also suggest the district's 'degree of freedom', - that is, its energetic constraints to action.[38] The maps shown previously depict how denim stores replaced quilt shops and souvenir sales edged out furniture in the bazaar. While these transitions can be attributed to a shifting marketplace (foreign tourist exports replacing domestic and household goods), the variations are constrained within certain sectors – textiles and household goods, respectively. Thus, innovation is supported, but within parameters that maintain existing competencies (for example, knowledge of textile distribution or sewing techniques). Agents constrain their variations to exploit the presence of transferable routines, allowing them to refine their niche segments.

Over time, specialized tags present greater clarity regarding where particular goods can be sourced. These signals are especially valuable for visitors seeking specific goods. Tags in the bazaar act like tags in eco-systems where, for example, a patch of flowers signals a general niche, while an orchid's distinct shape alerts a particular bird to a receptive 'match' for pollination. Tags increase an environment's legibility for actors seeking specific products. That said tourist flows increasingly dominate the major arteries of the bazaar. As many of these shoppers do not have specific goals in mind, the market's major streets are becoming heterogeneous. Goal-specific tags that orient behaviours are being subsumed by mechanisms that enable random search.

E   DISTRICTS: Emergent features of CAS

While certain sectors of the Grand Bazaar are becoming more heterogeneous, there is an overall persistence of distinct districts. These districts correspond to the emergent structures discussed in CAS: coherent entities that develop from the bottom-up. While the bazaar has governing bodies that deal with security and repairs, there are no authorities that partition it into districts. A merchant's only constraint on locational choice is the presence of available rental space. And yet, in the absence of rules governing locational choices, distinct clusters emerge. The urban framework of the bazaar (and its environs) is due to its inherent spatial elasticity, well suited to enable this clustering. Contiguous districts expand and contract depending on each shop's market capacity. The maps above show how the jewelry district, as an example, extended to the west as its market share grew. Its success became evident through street tags, which encouraged new start-ups to enter the growing sector. This expansion could occur incrementally because of the flexibility of the underlying urban grain.

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38   Also referred to as 'enslavement' - see Haken, 1980

Districts expand and contract as merchants opt for one of two evolutionary tactics: developing within a successful market segment or creating a new market niche (climbing a fitness peak or jumping to a new peak). Both strategies carry advantages and risks. Souvenir shops appear relatively low-risk due to high tourist demand, but the volume of low-skilled actors competing in this sector means that individual profits might be minimal. John Holland likens this trade-off to a game, wherein players line up in a queue to collect a resource payoff: 'as the number of players in the queue increases, the payoff per individual decreases. The longer the queue (or the larger the district), the more 'crowded' the niche' (Holland, 2012). To avoid this problem, agents can move to queues where there are fewer resources, but also fewer competitors. Thus, while some shops deal in high volumes with relatively low-priced tourist goods, others market expensive collector items. Both survival strategies are found within ecosystems, in which some species compete for abundant food resources, while others extract scarcer but less sought-after forms. The size of the district represents the 'carrying capacity' of the queue, or the number of agents that can be supported by a particular resource segment.

In the bazaar, some streets offer total homogeneity, whereas others are punctuated by unique offerings, or 'tests' of innovative products. Recently, a series of Turkish Delight (*lokum*) shops opened on the bazaar's main silver/gold street. The appearance of these new shops exemplifies attempts by new merchants to exploit high volumes of tourist flows on this major artery. As the carrying capacity of silver/gold is reached, other strategies are tested. Thus, spatial contiguity is counter-balanced by new niche tests **[Figure 7.16]**. Shop owners evaluate the potential payoff of a given queue and switch queues (test a different niche) if they believe the new one will yield greater resources. My interviews showed that within the bazaar, almost none of the merchants who were in business for generations had remained in the same sector. Instead, switching queues has proven a common response to market forces. Morton and Küçükerman also make this observation, noting how, '*Hakan Yılmaz, [...] attributes his third-generation presence [in the Bazaar] there to his adaptation abilities. First he made furniture, then he dealt with cotton textiles, and since 1995, he has been in towel manufacturing*' (Mortan and Kücükerman, 2009, page 223).

Districts that flexibly expand and contract according to the market's potential not only effectively allocate resources to agents, but also create efficiencies between them. Resources regarding market trends and access to customers seeking a particular product travel more fluidly between shops in close proximity. Thus, co-located shops offering similar goods tend to gain competitive advantages over their isolated counterparts. Subsequent entrants to the market increase their chances of success when located near clusters, which prompts increasing returns and positive feedback loops for co-located groups. Studying industrial agglomerations, scholars of EEG examine these phenomena, noting:

[Firstly] geographical concentration of industrial activities can generate agglomeration economies fostering start-ups and innovation [...]. Second, geographical concentration of firms increases the level of competition and makes exits of firms raise the average fitness of routines. Third, spatial concentration of firms can also affect the opportunities of collective action as such initiatives are more likely to emerge among proximate agents that can more effectively control opportunistic behaviour. (Boschma and Frenken, 2005, page 294)

A   Prayer bead shops in Uzun Çarşı Caddesi, north of Bazaar.

B   Ribbon shops: streets north of Bazaar.

C   Children's wear arcade: Passage Street, North of Bazaar.

D   Silverware: Kalcılar Han.

FIGURE 7.17   Various District specializations

Scholars of EEG observe how: *'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 and Lambooy, 1999, page 418). Stabilized districts then develop networks of complementary functions – tea merchants, restaurants and barbershops, for example – as synergetic clusters of functions that catalyze further economic and social transactions.

Despite such efficiencies, the erosion of district cohesion occurs (as previously mentioned) within the most touristic areas of the bazaar. Tourists engage in random searches seeking generic 'souvenirs' that can take many forms, such as carpets, scarves, lamps or ceramics. These visitors do not seek spatial cues to inform their search, which results in fewer efficiencies brought about by the clustering of sectors. By contrast, products that still cater to local flows (books) or highly specialized flows

(currency exchanges), maintain greater district contiguity. Furthermore, market streets that are just north of the bazaar maintain high levels of specialization and contiguity. Shops selling military supplies, lingerie items, bedroom fabrics, prayer beads (*tesbih*) [Figure 7.17a], ribbon supplies [Figure 7.17b] and children's wear [Figure 7.17c] represent a sample of the many programs that coalesce into specialized pockets. In addition, there is greater coherence of distinct *han* merchandise outside the bazaar [Figure 7.17d]. It appears that a certain amount of repeat traffic is needed to maintain coherent districts, while areas constantly frequented by newcomers provide fewer of the benefits associated with co-location.

§ 7.5 Conclusion

This paper employs an analytical framework that treats Lynch's urban 'objects' as CAS 'operational' categories, to examine how the behaviours of Complex Adaptive Systems are supported within Istanbul's Grand Bazaar. CAS processes do appear to manifest within this area, with the urban fabric enabling complex dynamics to unfold. Individual shops – as malleable agents within this system – track an evolutionary course of testing viable strategies, and where synergies exist, develop into discernible emergent districts. The urban system's ability to develop complex operative features is supported by both the flexible and redundant nature of street networks (that allow for variations in flows), as well as the existence of urban elements that test and stabilize connections, including infrastructural anchors and informal junctions. When my mother and I stepped into this complex pattern of interacting networks and flows, we were unwittingly guided into one such juncture.

Analysing complexity at the scale of the bazaar can only illuminate complex interactions that operate at this particular field of magnification. Considering other scales of behaviour would require us to switch the depth of field of our analysis. The bazaar constitutes a complex system, but it is also a node within Istanbul's larger complexity. At the scale of the city, the bazaar is itself a landmark: a place where global forces of change conflict with local patterns of continuity.

These competing forces reverberate within the walls of the Grand Bazaar, threatening its unity. At the same time, these pressures are key to the market's ongoing transformation, innovation and renewal. While distinct districts within the bazaar have emerged in the absence of top-down control, the presence of transient user groups erodes the ongoing stability of these districts. Certain forms of local hubs remain present, but, unifying global nodes and landmarks have disappeared. These changes point to a loss of common cultural values within the bazaar, a split lamented by many in the community. While many merchants expressed concern with the infiltration of cheap, mass-produced goods into the Bazaar, from a complexity perspective, the successful coexistence of mass-marketed and traditional goods is perhaps illuminating: it highlights the bazaar's inherent ability to respond to change, while maintaining stability. As one interviewee observed: '*the Bazaar is like a living organism: it keeps changing all the time*'.

Continuity and change find spatial expression through an urban fabric that is able to reinforce, reproduce and relay shifting competencies. The urban landscape thus absorbs and reflects new traditions, economic patterns and cultural norms in an ongoing adaptive process that sustains and breathes life into Istanbul's Grand Bazaar.

PART 4 — Augmented Morphology - how information technologies allow us to re-read the city
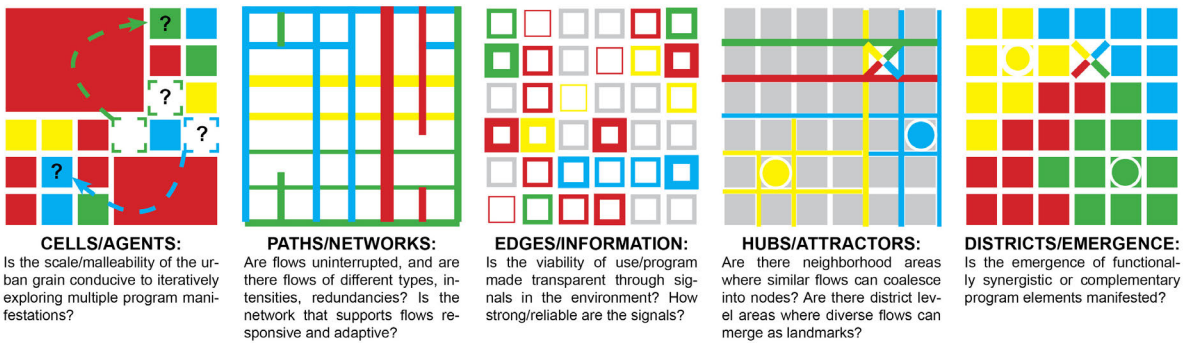
Introduction to Part 4

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In order for computation to emerge spontaneously and become an important factor in the dynamics of a system, the material substrate must support the primitive functions required for computation: the transmission, storage, and modification of information. Under what conditions might we expect physical systems to support such computational primitives? (Langton, 1990, page 12)

Thus far, the core argument of the thesis has pertained to how morphological features of urban fabric help enable complex urban dynamics to unfold. Part Three took the position that:

1. Shifting functional delineations of urban fabric (manifesting as global patterns or clusters of use), can be seen as an example of complex adaptation and emergence;

2. The physical composition of the urban fabric has a bearing upon the degree to which shifting delineations can occur and, the capacity for urban environments to manifest emergent features;

3. Insights from the field of Evolutionary Economic Geography (EEG) can be extended so as to incorporate a more explicitly physical dimension to the factors yielding emergent behaviors;

4. Criteria can be established regarding how urban fabric would need to perform in order to foster emergent dynamics;

5. These performance criteria can be enabled through the curation of particular physical urban features.

Part Three concluded by analyzing the Grand Bazaar, indicating that a CAS analytical framework could be employed to unravel certain evolutionary processes occurring in the Bazaar that lead to the emergence of districts. The article argued that the Bazaar's physical environment contains morphological features that support this unfolding. The article employs the Lynchian framework to 'unpack' the Bazaar's dynamics, considering the nature of its cells (urban grain), paths (urban flows), edges (urban signals), hubs (urban information transfer), and districts (urban emergence). Considering each urban element in turn, the analysis considers how effectively each urban attribute contributes to enabling CAS dynamics **[See Below].**

CELLS/AGENTS:
Is the scale/malleability of the urban grain conducive to iteratively exploring multiple program manifestations?

PATHS/NETWORKS:
Are flows uninterrupted, and are there flows of different types, intensities, redundancies? Is the network that supports flows responsive and adaptive?

EDGES/INFORMATION:
Is the viability of use/program made transparent through signals in the environment? How strong/reliable are the signals?

HUBS/ATTRACTORS:
Are there neighborhood areas where similar flows can coalesce into nodes? Are there district level areas where diverse flows can merge as landmarks?

DISTRICTS/EMERGENCE:
Is the emergence of functionally synergistic or complementary program elements manifested?

While the Bazaar study focused on unpacking an *existing* setting using this frame of analysis, the same lens could equally be employed as a design tool for developing a *new* setting. By considering the design of various urban features in turn, one could deliberately design environments - or as indicated in point five above, 'curate particular physical urban features' - such that the urban fabric would more easily 'foster emergent dynamics' (point four above). This framework is, therefore, not only intended as an analytical tool, but as a kind of design 'checklist' that offers designers a new way of strategizing their development of urban fabric. The checklist would help in understanding the variables involved in producing a responsive urban fabric that holds the inherent flexibility to adapt to unknown futures (which, so often, thwart our best planning efforts). This, of course, is not to imply that the ability to respond flexibly should be the only (or even the main) driver of urban design, but rather to suggest that it is worth incorporating this aspect as an additional design parameter. This checklist, thus, serves not to produce a particular *aesthetic* goal (which remains a design priority) but rather to establish an urban fabric that can serve as an ongoing information-processing unit.

I use this term, 'information processing' very deliberately here, despite its counter-intuitive nature when thinking of the built environment. All CAS, in some way, act as information processors. While we tend to think of this phrase as dealing with artificial computation, in fact it can be applied to a much broader array of phenomena. Each celllular unit of built fabric within the bazaar is receiving an input from the environment and reacting with an output of behavior, in an attempt to optimize its performance in space.

This notion that the urban fabric can be percieved as a- computational environment begins to inform the research in Part Four, which looks at how new 'digitally enabled' physically settings can help steer CAS processes. While at first glance this topic may appear to diverge from the work preceeding it, I would argue that these differences are more a matter of degree, than of kind. Part Four argues that, in the near future both the flexibility, and the signal-carrying capacity of urban experiences will be amplified through the incorporation of digital technologies in a virtually enabled world. The articles posit that digitally augmented urban experiences will gradually enhance:

— the ability to transfer information between urban agents (both human and physical) in ways that are more fluid, more seamless, and more tuned to specific circumstances;
— the ability for urban artifacts to enact transformative behaviors without need for human/artifact imbrication;
— the ability for human agents to enact new, information steered behaviors through an imbrication with virtual sensing devices;
— the speed and fidelity at which emergent, self-organized urban phenomena manifest.

Thus, while the research differs to a certain extent from the work that precedes it – which focused strictly upon the kinds of morphological features of the urban fabric that make it more amenable to evolving over the course of time - the identical principles remain at play. As in the earlier examples, principles such as information transfer, feedback processes, stigmergic signals, parallel agent testing, and degrees of freedom, remain key to mobilizing CAS dynamics. Thus, the core rationale of why complex adaptive processes come about remain the same. It is simply the *medium* for information channeling and processing, the *means* by which inputs and outputs are channeled, and the *kinds* of flexible responses generated, that shift.

The first article, *'Conceptualizing urban infrastructures as 'smart', decomposable, and information-processing agents'*, argues that material components of cities can be conceived as information processing agents, much like the automata in computational models that respond to surrounding conditions through a series of rules. With the coming 'Internet of Things' (IOT) these rules can be programmed into urban artifacts themselves: triggering autonomous local outputs in response to local sensor inputs. Similar to Cellular Automata, the cumulative outputs of the individual material agent processors may exhibit unexpected, emergent, fit traits. The article outlines a series of speculative projects (engaging research by design), that outline the kinds of viable urban systems that would be able to autonomously calibrate fit outputs in response to sensor-driven inputs. The projects are chosen from work executed by students to whom I teach a course on complex adaptive systems and architecture. This speculative research takes the premise that:

— discreet urban artifacts can be seen as 'agents' in a complex urban system;
— certain behaviors or manifestations of urban artifacts are more 'fit' than others (for example, both an overflowing and a consistently empty trash receptacle are 'unfit' urban agents);
— agents gain more capacity to be 'fit' if they have an embedded affordance to alter how they manifest (such as shifting function or shifting spatial position);
— the selection of which potential behavior a given agent should manifest can be steered in accordance with feedback signals;
— processing and broadcasting information about whether or not particular outputs regimes achieve a given outcome (relative to other agents) can help steer overall system behavior.

The research highlights how new information signals, channelled through the internet of things, might better enable urban agents to adjust their behaviors. These signals take the form of either sensor-generated data (employing sema-tectonic stigmergy) or crowd-sourced ratings (employing marker-based stigmergy). Each offers a kind of 'digital pheromone' that can steer system behavior. These can augment or replace the need for both the physical pathways that channel flows and the physical stigmergic signals carried within the built fabric (each of which were discussed earlier). Here, virtual signals replace physical signals.

Further, once virtual signals are conveyed (through sensors or apps), new augmented urban artifacts may eventually hold the capacity to deploy new actions without need for direct human intervention. While humans remain a key part of the system, they now operate in the role of a signal generator rather than being required to physically enact shifts to the material configuration of the urban substrate. Thus, a trash can that is empty, but able to sense that an adjacent trash can is overflowing may not only be able to remotely sense this data, but also autonomously relocate in response to the data. Both these new augmented capacities - data-driven information processing and the ability to autonomously shift performance regimes – would seem to suggest new potentials for a kind of urbanism that is able to generate emergent outcomes through bottom-up interactions or, to borrow a phrase from Neil Leach, a 'swarm urbanism'. Further, in this particular 'bottom-up' conception of a smart city future, there is no need for central, authoritarian 'command and control'. Instead,

each agent within the system is able to process information about its immediate environment and autonomously adjust its behavior in response to variations in steering inputs.

The second article in this section, '*Sensing the City: Legibility in the context of mediated spatial terrains*', attempts to engage more speculative, and, potentially ethical dimensions of this research. The paper considers how CAS dynamics can be enabled by a hybrid system of unfolding that fuses both physical and virtual processes. In this hybrid context, physical processes still take place on the ground, but some of the aspects of 'learning' (via information transfer), are supported by virtual signals that, in turn, help steer what happens in the physical world.

The article argues that, in an increasingly digitally mediated world, we have new capacities to 'self-curate' urban experiences. Here, I return again to Lynch and his ideas about imageability. I suggest that Lynch's static urban archetypes might ultimately become more fluid – replaced by virtual terrains navigated through mediated experiences highlighted by our smart devices. I argue that new kinds of paths, landmarks, edges, and nodes can emerge as a response to individual desires and trajectories. Again, the processes whereby particular instances of urban experience are highlighted come into being through emergent processes – the bottom-up crowdsourcing of 'trending' environments, for example - but this article places a greater emphasis on how Lynch's imageable environments become much more transitory and user-specific.

The previous section of the Ph.D. discussed ways in which morphological flexibility would allow the range of urban manifestations, or what I refer to as the 'phase space' of the urban, to be increased. That is to say, affording morphological flexibility implies that more of the latent flows or desires that have the potential to become moored (anchored in physical place), can be accommodated within the urban fabric. This section alters the lens from which these dynamics are considered. Work on the Grand Bazaar spoke about the forces of consumer desires shifting the behavior of Bazaar shops, with differential flows of these desires altering the physical manifestation of the Bazaar. But the focus was less about the flows themselves and more about the Bazaar's embedded responsive capacity to these. In this article, I take the same process and consider it from the perspective of the flows (or user desires) themselves. Rather than shops altering their offerings and their distributions to better correspond with the trajectory of consumer flows, might the trajectory of user flows alter in order to better align with the offerings of the Bazaar? In the case of the Bazaar, I had emphasized the importance of shops in the Bazaar having a straightforward ability to reconfigure so as to access user flows. In this case, I focus on how urban flows might be enabled to easily reconfigure in order to access urban offerings. I argue that mobile devices afford this new flexibility with, once again, information signals and stigmery being key. By virtue of smart devices' ability to highlight relevant, user-specific information, users are enabled to find specific urban offerings (ones tuned to their particular needs). Further, users are enabled to access these offerings in more fluid ways (by calling upon a range of app-based services such as uber, for example), thereby shifting the sense of distance and proximity in ways that make seemingly remote offerings suddenly accessible.

Here, as noted in the previous article, notions of agency become blurry, with the urban fabric altering in response to user input, and users changing their patterns so as to better align with information regarding spatial opportunities. With this co-evolving in place, new kinds of nodes, landmarks, paths, etc. begin to emerge in response to real-time needs and shifting patterns. The city becomes much less static, and user experience is much more individuated. Further, the convergence of multiple flows can generate feedback loops, such that new urban offerings 'emerge' as popular sites or, as Lynch would put is, as nodes within the fabric. These nodes are no longer spatially static but are, instead, shifting and enabled by virtual information flows carried on our smart devices. Similar to the article addressing New Urbanism's focus on the static qualities of the urban fabric versus the fluid, process-driven notion

of a CAS generated environment, this article begins to push the boundaries of what such a virtually augmented environment might ultimately entail, and how this alters our sense of traditional urban 'legibility'.

On the one hand, this reading of potential urban futures might be seen as emancipatory - rather than being restricted by norms of top-down control, we are granted a new, personal way of discovering our own emergent trajectories through space. That said, there is also a risk that too much self-curation will lead to the formation of parochial echo-chambers. While self-organization can lead to the discovery of individual niches, tuned to particular urban needs, this may pose problems if it results in a partitioning of urban territories into insular enclaves.

While the bulk of the Ph.D. research focuses on the mechanics of how a city might self-organize through activating the bottom-up agentic power of the urban fabric, it does not comment on the ethics of such an urban environment. As the last article in the dissertation, this contribution takes a more critical stance of some of the ethical issues such an urbanism might generate. The sorts of experiences we associate with urbanity – including exposure to unfamiliar and occasionally uncomfortable encounters – may be 'filtered out' as we begin to navigate urban territories in highly tuned and specific ways.

The final coda of the thesis returns to this discussion of the importance of urban encounter, highlighting urban nodes that belong to all, rather than being niche specific.

As a final note, in introducing these particular articles, I would be remiss not to acknowledge the important contribution of my research students at Iowa State University. Much of this research was developed while teaching a seminar course in Complexity and Urbanism. I am indebted to the creative energy of my students who come with a sensibility that is highly sensitized to the new reality of living in a highly mediated world. The thought-provoking work that these students spearheaded as part of their engagement with the course material provided much of the fodder for these future research directions.

8 Conceptualizing urban infrastructures as 'smart', decomposable, and information-processing agents.

Abstract

This paper considers the speculative design of a series of urban amenities - a bus system, a floating pedestrian bridge system, a bike-share system, and a small-scale commercial area - each conceptualized as a Complex Adaptive Systems. In each case, rather than the solution to the problem of each system's spatial configuration being imposed from the top-down, it emerges from the bottom-up. Each case considers how, given the growing pervasiveness of digital signals, information can now easily be transmitted amongst both human and non-human 'smart' entities. The fact that such entities might include physical urban elements creates new capacities for organizing these: ones leveraging sensor inputs, bottom-up processes, and 'the 'wisdom of crowds', to allow fit urban configurations to 'emerge' over time. The projects thus outline how 'fit' urban configurations might viably manifest in the absence of top-down control.

This paper outlines the principles of these thought experiments, reflecting upon implications for advancing research in operationalizing urban Complex Adaptive Systems (CAS). Although CAS research into urban phenomena has been pursued within a wide array of discourses (computational, communicative, and assemblage perspectives, to name a few), these approaches generally do not engage a real-time *in situ* unfolding of CAS. This paper provides an alternative conceptualization: one that conceives urban elements as physically situated computational devices capable of processing information regarding their own fitness. These elements are then designed with the capacity to aggregate into meaningful emergent patterns, as well as partition to fill multiple niches meeting a plurality of needs. The paper thereby frames a novel way of operationalizing CAS principles within urban design research.

Key Words

Complexity science, emergence, design methods, self-organization, smart cities

Introduction

In recent decades, research embracing complexity principles has become increasingly prevalent in a wide array of fields, spatial planning being no exception (Portugali et al., 2012; Sengupta et al., 2016). However, while the power of complexity, with its 'bottom-up' rules, and 'emergence' of fit configurations, is intriguing, it is also often difficult to understand and operationalize. Understanding CAS dynamics is challenging in and of itself, and then determining how insights from the source

domain (complexity studies) might best inform the target domain (urban planning), remains unclear (Chettiparamb, 2006).

Computational geographers, communicative planners, and assemblage geographers (to name but a few), each import concepts from CAS, albeit in different ways (see Chapter 4). That said, these discourses pay little explicit attention to how the elements of urban form might be conceptualized as a kind of substrate upon which CAS behaviours unfold. That is to say, how the *material elements* that together compose urban fabrics - be they park benches, bridges, buildings, parks, roads, streets, etc. - might be conceptualized as elements that operate as unfolding complex systems.

Beginning in 2015 I have taught an upper-level seminar course on Complex Adaptive Systems in the College of Design at Iowa State University. The course, entitled *'Complexity Theory for Resilient Cities and Architectures'*, provides an introduction to the principles of Complex Adaptive Systems Theory and their application for the making of flexible, responsive, and resilient spatial environments. The course focuses on understanding the nature of complex systems - self-organization, emergence, networks, agent rules, evolution, etc. - and then moves on to apply this understanding to various spatial problems.

At the conclusion of the course, each student produces a speculative design proposal illustrating how CAS dynamics might be activated in urban contexts to produce projects that evolve over time, leading to 'fit' emergent conditions derived from the bottom-up. Students consider the nature of actors or 'agents' within the system, the forces driving adaptation, the fitness parameters governing behaviour, and the mechanisms whereby information and feedback loops might steer the system.

Unlike most engagements with complexity, these speculative projects focus upon how physical components within the urban environment might be designed so as to behave as complex systems. Here, particular components of the urban fabric are distilled into agent classes, with members of these classes then treated as computational devices that can each receive inputs regarding their behaviour in space, and are then endowed with the capacity to adjust these behaviours in response to these inputs. By focusing upon how *material artefacts* might be designed so as to support and enable the unfolding of complex urban processes, the studies begin to suggest unique strategies for engaging complexity within urban studies.

This paper provides an overview of four of these projects: a bus system; a bridge system; a bike rental system; and a retail district. Each is conceptualized using CAS theory such that the solution to the problem of each system's spatial configuration emerges from the bottom-up. While the proposals are diverse, they derive from the same general set of assumptions regarding the nature of self-organizing systems, following from John Holland's work (1995, page 23). Students therefore consider:

1 *The nature of the* **agents** *seeking fitness, and how these agents can be designed so as to have multiple capacities, or 'degrees of freedom'.* Agents are conceptualized as 'smart' urban elements designed with the capacity to be mobile or mutate their functions.
2 *The nature of the resources or* **energy** *driving the system.* Each element is designed such that its capacities 'feed' or channel urban demands. Accordingly, how well each element is 'used' or 'activated' is predicated upon its capacity to 'satisfy' or channel particular urban flows.
3 *The nature of* **links** *or* **information** *steering the agent.* For each system, students identify a source of feedback or information that steers behaviour, as well as how this information is relayed and become actionable.

Using these principles, each project outlines how, over time and in non-linear ways, interactions amongst agents could steer *emergent* urban configurations in accordance with feedback about each agent's level of activation (and thereby its fitness). The work is predicated upon a rethinking of how urban elements might be conceived in ways that allow them to behave more similarly to autonomous agents in CAS - conceptions that involve both greater system partitioning (decomposability), as well as an emphasis on transformation or mobility such that new behaviours or configurations are made possible. Finally, each sub-element must incorporate the capacity to process information, which relies upon integrating 'smart' features.

The first section of the paper provides an overview the four student projects. The second part considers the works as a whole, noting recurrent themes and orientations. Together, the studies begin to illuminate the kinds of mechanisms required for self-organizing complex dynamics to ensue. I conclude with implications of this research, noting that rather than attempting to analyse urban problems and then propose or 'forecast' solutions, the experiments partition urban problems into distilled elements, and then identify processes and mechanisms whereby parallel urban agents would 'solve' these problems *in situ*. The work illuminates how urban settings might be 'primed' so as to have this capacity to evolve over time, in responsive ways, and in accordance with user needs and site dynamics.

§ 8.1   **Part 1: Overview of Projects**

A   *Urban Lemna: 'A floating bridge system that relocates in response to user feedback' (Chunyao Liu)*

'Lemna' is a form of duckweed that drifts along water as a single unit or in large clusters that constantly shift and re-arrange. Inspired by this precedent, Urban Lemna rejects the fixed and rigid infrastructure of urban bridges, by decomposing these into responsive floating platforms able to aggregate with one another using magnetized interfaces. These platforms, guided by apps, are both self-propelling and 'smart': equipped with sensors that monitor their use. Individuals in the city log onto an app and see where bridges are currently formed and either go to these bridges or post a request for a new bridge at a 'preferred' location. When crowd-sourced demand for a particular bridge location is high, the platforms will respond by migrating to these areas. App users would then see how long they must wait for a new bridge to form, versus how long it would take them to complete their route using an existing bridge.

Each floating component is equipped with sensors to monitor usage, enabling them to obtain feedback on whether their current usage rate is high or low. Platform components are plentiful enough that different widths of bridge structures can emerge, with some bridges being very thin (one platform wide), and others growing wider in response to feedback. If usage patterns correspond with current locations, platforms will tend to stay in place. But if a disjunction emerges between where platforms are located and where numerous users would like to see a new bridge, or if platform sensors detect that their frequency of use is low, the bridge can either thin down or de-aggregate entirely and relocate.

Within this system, the agents are the mobile platforms designed with the capacity to relocate. Feedback comes in two forms: crowd-sourced bridge requests and sensors indicating how frequently

a platform is being used. By means of this feedback, 'fit' bridge locations with widths that 'sync up' with actual pedestrian flows emerge over the course of time. Bridges can alter their widths at different times of the day or week or relocate altogether in response to shifting urban flows.[39] As bridge locations stabilize, pedestrian patterns shift, such that the relationship between bridge locations and pedestrian activities co-evolve over time.

B   *Self-Organized Planning: 'Crowdsourcing District Functions with Mobile Infrastructure' (Brad Wicks)*

This project outlines how the placement of functional civic amenities might be tested and crowd-sourced by means of tactical 'mobile vendors' (similar to food trucks). Here, citizens make use of an app that allows them to either find or request a particular mobile-vendor (the agents in the systems). These mobile vendors have the capacity to support different kinds of urban functions (food vendor, clothing store, gift or shoe shop, etc.). The agents, similar to 'pop-up shops', are deployed at various locations within the city, initially populating sites at random. However, users, by means of an app, can indicate what kinds of amenities they would like to access within their particular neighbourhood thereby providing information to steer the system. Vendor units have the capacity to alter their behaviours in two ways: by relocating to zones that seem to have high demand for their product, or by switching product-lines to correspond with those in demand at their existing location. Furthermore, vendor units must relay information regarding their popularity amongst each other. In this way, districts that request a particular amenity but then fail to patronize it would be disambiguated from areas that are popular and frequented.

Students speculated that, over time, clusters of differential use and sizes of vendors would emerge in different districts. Once usage patterns stabilize with a number of mobile amenities remaining consistently in place over longer periods of time (due to ongoing demand patterns), the city would invest in a permanent structure to host these amenities – an 'emergent' shop district catering to a particular niche. The mobile vendor units would then be leased to new entrepreneurs who could move on to explore other latent shopping demands.

Here, the city is conceptualized as holding inherent capacities to support different kinds and densities of retail goods, but the specifics of these capacities are initially unknown. We can think of these latent capacities as distinct niches that might be occupied in optimum ways, and the mobile vendors as agents that 'search' for the most viable niche within which to survive, given their particular area of competence. They are, therefore 'fitness probes', steered by information regarding how well similar agents perform in a given location (as per Chapter 4). Similar to the floating bridge system, mobile vendors are guided both by crowd-sourced signals obtained through apps, but also signals that relay actual user patterns – such that a shop encountering large volumes of business relays a signal to similar shops, indicating that the niche it is occupying might hold untapped carrying capacity.

Accordingly, '*rather than putting all resources into a large idea that might fail, this method of city planning operates using CAS principles by providing a platform of parameters that allow ideas to be tested out in the real world by agents before they are implemented [...] to create an emergent urban landscape that is self-organized from the bottom up by citizen's actions*' (project text).

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39   While this project was proposed in the course as a speculative idea with no precedent, shortly afterwards (September 2016) an almost identical prototype was initiated by the Carlo Ratti team (MIT) for the City of Amsterdam as a real project - http://mentalfloss. com/article/86316/autonomous-boats-are-coming-canals-amsterdam.

C *U:Bus: 'A Self-Organizing Bus System' (Brad Wicks, Dylan Russ, Chunyao Liu, Belma Mehic)*

This project suggests a self-organizing bus route system for a college-town. The town is divided into various service districts each of which has buses circulating from that zone to the University campus within 30-minute cycles. Each zone is subdivided into a grid of 'potential' bus stops, equally dispersed at 650 feet apart. An app serves as a GPS for the buses, while also collecting data from riders to calculate which stops the buses should go to and in what order.

Individuals open the app and are shown a map of all possible bus stops. This can be considered in physics, as the 'phase space' of all potential bus trajectories. Within this phase space of potentiality, each stop is considered as a potential attractor point. When users select their 'preferred' stop, the app indicates both the wait and the walk times for that location. Users may opt to wait at a stop closest to their present location but may have longer waits if other stops have higher demand. Alternatively, they can walk to an adjacent location where others have already requested service and have access to a bus arriving more promptly allowing, *'users to explore their [travel] options based on their own criteria and pick the bus stop that best fits their criteria'* (project text). Users indicate their course of action, which then sends a signal to the system. Based upon these signals, buses 'weigh' their trajectories, factoring in the number of riders present at a given stop, the travel time increase required to add new stops, and the wait times associated with unmet pick-up requests.

Initial bus routes are essentially random, constrained only so as to ensure a wide swath of coverage and a maximum total running time to reach the university. However, as individuals elect to go to a particular bus stop, that stop's wait time decreases, which in turn attracts more people. If a bus is in close proximity to a stop occupied by a single user and there are no competing rider requests, it will alter its route to pick that rider up. However, if other requests are present in the system, the bus will divert to the stop with: a) the highest critical mass of riders in close proximity; or b) the longest currently unhandled service request. The actualized route of the bus is then determined in real time by weighing different viable pathways in accordance with this algorithm.

Stops that initially attract a high degree of ridership are given preferential weighting in subsequent circuits. Thus, over time, the original random route is steered by decisions made on previous trips. The students speculated that, over the course of time, certain 'attractors' stops within the bus loop would emerge. Users who are frequently re-directed to such an attractor would likely begin to gravitate to that stop on subsequent trips, because of recurrent feedback that going to their preferred stop yields longer wait times. Nonetheless, they may still opt to go to their 'preferred' stop, so the system can support a range of choices.

Here, both individual buses and individual riders are considered as co-evolving agents within the system, each of which has the capacity to alter their trajectories. These trajectories intersect at emergent 'stop' locations: points in phase space where the frictions associated with long waits and walks (for the riders) and long routes with low ridership (for the buses) are minimized. While routes will stabilize, every new semester a large system perturbation (or disturbance), disrupts existing route patterns in order to avoid 'lock-in' behaviours that might entrench routes that are no longer 'fit'.

D *Cybike: Self-organizing user responsive bike share hubs (Deep Chaniara, Karl Poley, Evan Jeanblanc)*

This bike sharing system for a college town uses 'smart' technologies to allow bikes to self-organize their 'hub' or pickup/drop-off locations. Bikes within this system are partitioned into a series of bike hub 'units' (the agents), consisting of a small trailer holding two bicycles scaled to fit within a standard

parking stall. Bike-hub agents stationed in locations where they experience high turnover levels are considered to be 'fit' whereas bike-hub agents stationed in locations where they are left idle are considered unfit.

When bike-hub units remain idle at a given location, they broadcast a notification (via an app) requesting to be moved. An individual (human) is then offered a ride credit in exchange for using one of the two bikes to hitch the trailer and move the hub-unit to a new parking stall location. New locations are determined either at random or are steered by information derived from other hub locations. If, for example, bike turnover rates at a particular location are high, then a signal is broadcast from this location requesting more bikes. In this way, bikes sitting idle gradually relocate to locations where current use rates are high, until such point as that location's carrying capacity is reached and bikes begin to sit idle. Bikes can then move to random locations where there may be a latent rider population that has not yet been activated.

Students speculated that over time, assemblages of bike hubs units would partition into bike-hub niches of varying scales (reflecting differing carrying capacities). It is interesting to note that while some of these niches might be quite small (hosting only one bike hub unit), or very large (hosting fifty units or 100 bikes in total), individual bike hub/agents are 'satisfied' or 'fit' regardless of whether or not they serve a large or tiny market. From the perspective of the hub-unit as an agent, as long as bikes are not idle for a long period of time the unit is 'fit': irrespective of the scale of the hub. In this way, the project is similar to the floating bridge platforms in that viable niches co-exist for both large and small-scale demands.

In this system, bike hub units are agents and their flexibility is in the form of their mobility that allows them to seek out new locations. Information/feedback takes the form of usage monitoring, and emergence takes the form of bike-hub locations and their sizes. The students also speculated about adding another variable within the hub's adaptive capacity, by allowing differential pricing for hubs to serve as another mutable factor for testing fitness at otherwise 'unfit' sites.

§ 8.2   **Part 2: Project Analysis**

Together, these projects demonstrate the capacity to develop a bottom-up organization of urban features, steered based upon real-time local information, where each agent in the system autonomously adjusts its behaviour so as to move towards 'fitter' regimes. In this way, we can think of the agents as being like cells in computer simulations: they are steered by simple rules and have the capacity to alter their configuration or behaviours in response to signals from their surrounding environment. But here the agents are not cells *simulating* urban objects but urban objects themselves; rules are adjusted not by modellers but according to the weighting of unfolding environmental inputs; and the lattice housing the agents is not a virtual terrain, but the physical terrain of the city. If computational modellers aim to understand civic dynamics by constructing agent-based or cellular-automata simulations that model real-world behaviour, then these projects show how real-world objects can be designed as computational devices: information processers that reorganize their behavioural outputs based upon inputs received from the environment itself.

This perspective echoes one recently advanced by Lars Marcus and Daniel Koch, who argue that '*the built fabric of cities needs to be understood as a highly intelligent artifact itself, rather than simple,*

dead matter' (2017, page 204). They frame this artifact as, *'an intricate, dynamic and multi-faceted system for the storage and retrieval of information related to a wide range of urban societal processes'* (2017, page 206). Accordingly, rather than the built fabric being an inert 'background' within which complex dynamics unfold, it is conceptualized as an active participant, responding to and imbricated with human users. A physical element's status at any given moment within the city here acts as a form of memory and retrieval system for human activities.

It should be stressed that this memory and retrieval capacity need not require what we currently refer to as 'smart' capacities. For example, grassy fields provide a medium that inscribes data regarding the movement of people along given trajectories, with the worn grass offering information regarding the popularity of a path. Similarly, the presence of a jewellery cluster in a bazaar, or the siting of moveable chairs situated in a park each signify something about human habitation and 'fit' arrangements in space. I have already discussed how such physically manifested signals (discussed below as a form of *stigmergy)* provide information that can steer patterns of use, generating emergent phenomena in the absence of top-down control. I argue that undertaking an explicit 'reading' of such physical information signals – or indicators of 'fit' behaviours – might be operationalized as a planning or design strategy.

But the student projects described here focus upon how such latent signals might be 'augmented' within urban infrastructures – computationally enhanced so as to sense and relay signals in explicit rather than implicit manners – thereby enabling processes of emergence and self-organization to occur with greater speed and fidelity. To achieve these ends, several characteristics of complex systems are integrated within each project and categorized in detail below (see [Table 8.1]. for a summary).

Key to each of the projects is determining the way in which urban functions might be disaggregated - transformed into **partitioned elements** that act as **independent agents**. In each project, urban elements typically viewed as wholes (bridges, bike-hire hubs, bus routes, shopping centres), are instead partitioned into disaggregated components. This partitioning (floating platforms, bike-hub units, potential bus-stops, mobile vendor shops,) permits each unit, acting in parallel, to test different strategies for achieving fitness (Holland, 2012). Here, 'fitness' (discussed below) is framed around how efficiently a particular *resource* or energy flow is organized by the system (Morowitz & Smith 2006).

We can think of this **resource as an input that 'drives' the system**: if there is no resource, then no system evolution can occur. As an example, we can think of ants seeking food as a complex system. Ant trails leading to food ultimately emerge due to the individual food-seeking behaviours of the ants. This search process is steered by means of signals (pheromones) that ants secrete upon encountering food. However, even though the dynamics of ants conducting random searches combined with pheromones providing signals will result in emergent pathways leading to food, this will not happen unless the *resource* of food is actually present. Similarly, in the example of the self-organizing bridge system, no organization can occur in the absence of pedestrians using bridges. It is their presence that 'drives' the system to evolve.

	Bike Hub	Floating Bridge	Mobile Amenities	Ubus
Agent Partitioning Strategy :	Two-bicycle hub units dimensioned to fit within a parking stall; Sensor-embedded trailer that can be moved by either bike.	Sensor-embedded floating platform wide enough for two people to pass; Deploy in tandem to form a length sufficient to span the river; Steered autonomously; Magnetized to allow locking onto other platforms.	Mobile vending units (vans) operated by individual owners/entrepreneurs.	Each bus is an agent/each rider is an agent.
Agent Adaptive Capacity (affordances or 'degrees of freedom')	Ability to be transported to a new location; Ability to change pricing levels.	Ability to autonomously navigate to new locations	Ability to test the selling of different kinds of products with low investment; Ability to test different sales locations.	Ability for bus agents to change routes; Ability for riders to move to different stops.
Resource/Energy driving the system	Bike ridership levels.	Pedestrian movement levels.	Sales levels.	Bus ridership levels.
Form of adaptation	Relocating to new bike locations ; Altering price levels.	Relocating in tandem with other agents, to form a new bridge location.	Moving to new locations and/or shifting product lines.	Adjusting trajectories (for each co-evolving agent).
Form of information steering adaptation	Sensors that monitor usage levels at all hub locations and are able to relay this to other bikes hubs; Random probes of novel locations to test untapped markets.	Crowd-sourced inputs requesting bridge at a given location; Sensors recording actual use levels at a given site and comparing this to other sites; Random probes of novel bridge locations.	Crowd-sourced inputs requesting products at a particular locations; Shared data collected from mobile vendors regarding sales volumes, locations, and product lines; Random probes of novel locations and product-lines.	App that provides information to riders about wait times and walk distances; App that provides bus with information about rider locations and length of time riders have been waiting.
Emergent outcomes	Hubs of different scales in different locations; Different price points.	Bridges of varying widths in varying locations.	Different scaled clusters of vendors selling particular ranges of products.	Bus route configurations
System Fitness criteria: (Minimizing processes)	Minimum overall number of idle bikes; Maximum revenues.	Minimum number of platforms recording low movement levels; Minimum number of energy expended on relocations required to maintain system at high usage levels.	Maximum profits for all vendors.	Maximum number of people arriving at their destination with minimum walk and wait times; Maximum bus capacity filled, with minimum route time.
Level of human agency/ imbrication required	Humans used as mechanism to transport bikes to new hubs.	Humans required for inputs into crowd-sourced desired locations.	Humans required to alter product lines sold, move the vending unit, and provide inputs regarding desired product locations.	Human agents decision-making regarding priorities in walking versus waiting provides the context in which the bus agents evolve their strategies.

TABLE 8.1 Comparison of student projects and CAS strategies

For CAS in general, as the intensity of a relevant resource or 'driving' input (order parameter) is increased (for example heat, or population growth, or food) more system states are made possible. As Francis Heylighen describes, '*one way to understand this is by noting that more energy "pumped"*

into the system allows more amplification of small differences (positive feedback), and therefore more varied types of behavior' (1999b: page 14). Thus, it is reasonable to speculate that as more pedestrians (seen as the source of input or 'energy' driving the bridge system) are present, the system has the capacity to enact multiple viable pathways. Normally, when speaking of bifurcations, we refer to the system 'choosing' one of these viable pathways to engage. In this case, the system need not necessarily choose. Multiple viable pathways can be enacted simultaneously, provided there is the requisite population flow (the necessary input) to sustain the different trajectories.   To illustrate further, we can imagine how at low population levels the only viable store within a city might be the steady state of a singular general goods store. However, as population (as a driving input/resource) increases, two stores might become viable: bifurcating viable niches into , for example, a co-existing food store and dry goods store. As populations grow over time, an increasing number of retail niches become viable until we have cities - like that of New York - wherein every possible market niche holds some carrying capacity: from pet groomers to Gucci stores.

Here, the urban environment is conceptualized as a kind of 'phase space' (Jones, 2009) that has embedded propensities to support differential uses, with these propensities remaining hidden or latent until such time as they are activated by resources. This phase space is uneven, holding differential latent capacities, which can be thought of as niches that might be activated or exploited in different ways. However, the way in which these latent capacities come to be channelled is contingent: that is to say, *which* capacities are actualized is subject to what historically unfolds or is enacted over time (DeLanda, 2005). Accordingly, initial random trajectories are strengthened by feedback dynamics, causing certain latent capacities to be strengthened while others are diminished. In the bridge project, for example, two equally viable bridge trajectories might be latent within phase space, but if one versus the other is initially deployed, this will, in turn, alter the nature of the phase space, creating feedback mechanisms that reinforce one trajectory while weakening the other. Accordingly, the propensities of phase space do not remain static. Once a bridge emerges it steers subsequent individual 'walking habits', strengthening its propensity to be walked upon. In this way, stable attractors (Kauffman and Johnsen, 1991; Pigliucci, 2008) or bottom-up, fit, structures come to be.

Emergent patterns are those that are 'in tune' with latent site capacities – that is to say, they are 'fit'. The concept of **fitness** is worth considering in greater depth. In physics, fitness is generally equated with entering into regimes that minimize energy expenditures or frictions. Consider the spherical volume of a soap bubble: molecules in a soap solution are attracted to this self-organizing form as the 'fittest' solution to the problem of enclosing the maximum volume of air with the minimum surface area possible. Self-organizing patterns in nature can generally be seen as in some way addressing such 'minimizing criteria': achieving the most with the least (Trenchard & Perc 2016). Fractal patterns in plants, as another example, carry the maximum number of nutrients to the greatest possible surface area with the minimum overall travel distance. Turning to an urban case, walking a straight line might be a 'fit' solution to the urban problem of getting from point 'A' to point 'B'. That said, the nature of the *relevant* 'fitness criteria' is not always straightforward. If the only process we wish to minimize is time and energy spent walking, then a straight line is a fit solution. But if we regard traffic noise as stressful, we might wish to minimize our encounter with noise and air pollution. This would involve factoring in other minimizing criteria, with the result that a jagged trajectory that minimizes sound and air pollution would be most fit.

In each of the student projects, it was, therefore, important to establish the relevant fitness criteria needed to evaluate agent success. Based upon these criteria, students would identify the signals most relevant for determining if an agent's protocols moved it towards or away from that goal. If fitness for a bridge is defined as 'being walked upon as much as possible' then platforms needed to be designed to receive inputs regarding whether or not their location in space served this end or not.

Relevant **information** is thus a key component of CAS. While an agent might receive many inputs, designs needed to focus upon what information *mattered* to constrain agent behaviours – or 'the difference that makes a difference' (Bateson, 2002). Here, information as a formal construct (described by Shannon as the reduction of uncertainty (1964)), constrains agent actions within a system, narrowing down the range of all possible actions to those that increase 'fitness'. Returning to the ant colony, pheromone traces provide a mechanism that helps steer agents towards food pathways, with overlays of pheromones providing a gradual 'weighting' of particular trajectories. Ant behaviour, though initially random, is steered over time by this information signal: with ants learning from both from their own behaviours and that of other ants in the colony (Gershenson and Heylighen, 2004). This parallel learning speeds up the pace of evolution.

Often, information took the form of a 'smart' capacity that monitored user preferences through crowd-sourcing apps, occasionally supplemented with ratings that evaluated agent behaviours once these were in place. This was the case for the mobile vendors, where both crowd-sourcing and the presence of many 'likes' for a particular item or location were seen as a kind of digital pheromone that helped vendors adjust their vending strategies (Parunak, 2005).

That said, the fidelity of these information signals remained dependent upon the nature of the crowd-sourcing environment. If inputs were sparse then results could be skewed and inaccurate. Accordingly, other sources of information needed to be considered. Here, students considered how they might operationalize the principle of **stigmergy**, the 'marking of action' that works as a coordination mechanism within complex systems (Grassé, 1959; Theraulaz and Bonabeau, 1999). Pheromones are a classic stigmergic signal: marking the detection of food and creating a signal to steer other ants. But significantly there are two main forms of stigmergy: marker-based and sema-tectonic (Heylighen, 2015; Parunak, 2005). Marker-based stigmergy involves an *active* decision to transmit a signal - like leaving a 'thumbs-up' or providing input regarding a preferred bridge location. This kind of signal, while useful, relies upon a high number of participants in order for the signal to be reliable, and also relies upon user wishes or anticipated needs aligning with actual needs. Sema-tectonic stigmergy, by contrast, is a kind of signal on 'auto-pilot': it presents itself by virtue of engaging with the system. Thus, if someone walks over a floating platform embedded with a sensor, input regarding its use is relayed regardless of user intentions. Sema-tectonic signals are thus less prone to error as they rely upon *actual* behaviours, rather than self-reported or anticipated behaviours.

By employing sensors that capture sema-tectonic signals, each urban agent is able to obtain an accurate picture of how it is being activated relative to all other agents. Less fit agents can then adjust their behaviours to correspond with that of more fit agents until such time as the carrying capacity of a particular behaviour is reached. At that point, all agents employing a similar strategy will begin to see their fitness decline, and some will then be motivated to seek out alternate strategies.

This re-alignment towards 'fitter' protocols can only occur if an agent can, in fact, alter its behaviour. Agents must, therefore, be designed with some kind of inherent **adaptive capacity** – a plasticity or mutability that allows them to shift regimes (Hooper et al., 2002; Kaneko, 2009)**.** In the student examples, this mutability generally involved the ability to relocate spatially, or the ability to manifest more than one potential function (such as a vendor unit manifesting as food truck, shoe store, coffee shop, etc.).

In some projects, this ability to switch regimes was fully automated (such as the bridge platforms relocating in response to sensors), but at other times the reconfiguration of an urban agent was highly entangled or **imbricated with human agents** (Leonardi, 2011). Accordingly, while the mobile vending agent has the inherent *physical* capacity to sell different kinds of products, this capacity is meaningless

unless coupled with *human* agency: a vendor who elects to change product lines in accordance with market signals. It is thus important to consider where and how human agents are integrated within the design of the system. That said, in all cases the *physical* elements in the system were designed so as to *afford* a level of flexibility for the testing of different kind or regimes of behaviour, thereby enabling the human agent to easily activate new potentials (Gibson, 1986; Leonardi, 2011; Marcus and Koch, 2017).

These **affordances** become part of the design itself and can be thought of as an intentional broadening of each agent's '*degrees of freedom*'. In physics, an agent's degree of freedom pertains to the range of variable parameters it can manifest. In the student examples, these included the capacity for an urban object to perform in diverse ways while remaining in place (functional mutability) or being designed in such a way as so its functional operations might easily be repositioned in space (locational mutability). In some cases, these were combined in order to take advantage of both functional and locational variables.

To summarize, I propose that the processes outlined above are analogous with John Holland's description of running an adaptive 'program', with urban agents seen as 'information processors' **[Figure 8.1].** Here,

Adaptive agents are defined by an enclosing boundary that accepts some signals and ignores others, a 'program' inside the boundary for processing and sending signals, and mechanisms for changing (adapting) this program in response to the agent's accumulating experience. Once the signal/boundary agents have been defined, they must be situated to allow for positioning of the relevant signals and boundaries. That is, the agents must be placed in a geometry that positions populations of agents of various kinds and localizes non-agent 'resources'. (Holland, 2012, page 24)
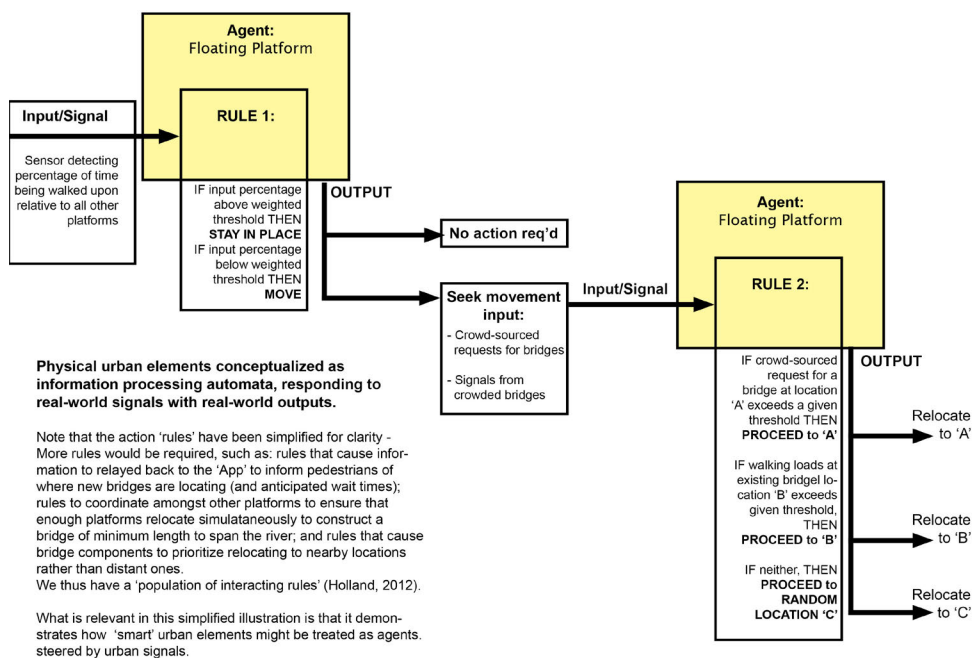

FIGURE 8.1 Urban Agents as Information Processors:

§ 8.3   Conclusion/Discussion

Complex Adaptive Systems considers how multiple agents, following simple rules, and responding to local signals, can generate emergent structures. The dynamics of CAS are therefore highly amenable to being modelled within computer programs using Cellular Automata or Agent Based Models (Batty, 2007a). This has been proven a useful way of operationalizing CAS dynamics to study cities. That said, limited work has considered how the dynamics of CAS might be moved outside of models that *simulate* urban contexts, so as to consider how CAS dynamics might be activated *within* urban contexts (there are exceptions, many of which eminate from MIT's Senseable City Lab. See for example (Kloeckl, Senn, & Ratti, 2012; Offenhuber & Ratti, 2014; Ratti, 2011))

The work above conceptualizes the particularities of urban fabric as *embodying* the properties that would allow cellular automata or agent-based systems to function *in situ*, with the urban environment conceived as the platform upon which computational variables are explored and enacted. The projects, therefore, begin to provide guidance as to the 'design criteria' needed for urban elements to enact the computations that normally are simulated within modelled environments. Furthermore, despite a growing interest in 'smart' embedded urban infrastructure (or the Internet of Things), research associated with 'smart' cities tends to be predicated upon a top-down processing of 'big data' rather than an activation of bottom-up agent-based processes (see, as an example, Kitchin, 2014).

Together the projects here show a range of circumstances whereby it is possible to conceptualize urban elements as decomposable and 'agent-like' populations, that can support the generation of novel, emergent outcomes. They demonstrate the capacities made possible by pervasive data for *real-time and responsive* decision-making, where inputs generate immediate signals regarding element configurations, and those configurations in turn shape user patterns. In this way, both the users of the system and the urban elements comprising the system are considered as co-evolving agents, with data transmitted between and amongst them.

While not all urban elements are necessarily amenable to such a conceptualization, the research points to consistent design principles or criteria needed in order for such CAS dynamics to play out in space. These primarily involve system partitioning, a means of receiving and transmitting information regarding fitness, and providing affordances for mutability. Perhaps most importantly, it requires considering the situated context of the agents as an environment holding latent capacities to drive differential use, and a thoughtful approach as to how these capacities might then be explored.

Despite these consistencies, certain ambiguities also appear within this conceptualization: are agents *users* of an urban amenity or are they *components* forming an amenity? Might both be conceptualized as agents – but ones that co-evolve? In discussing the *Ubus* system we realized that the system is composed of two sets of agents: riders 'seeking' a bus with minimum wait and walk times, and buses 'seeking' to travel from 'A' to 'B' in the shortest time while collecting the maximum number of riders. Each of these agents is steered by different dynamics or resource abundances and scarcities, yet the two agents co-evolve over time. We can also position the stops themselves as agents – whose fitness relies upon attracting both buses and riders. These agents enter into productive, mutual adaptive synergies as the shifting performance of one steers the shifting performance of the other. Here, the emergent behaviours of one set of agents become the *context* or input for other sets of agents. Accordingly, the notion of 'context' is not a static feature of complex systems but rather a relational one.

Similarly, identifying the 'resources' driving the system is not always straightforward. If the agent is conceptualized as a *user*, then 'energy' might involve gaining access to a particular urban amenity in ways that minimize frictions (be these travel times, costs, line-ups, etc.), but if the agent is positioned as the *amenity* itself, then the resource is being activated or 'used' at a certain threshold of intensity. Often during project conceptualizations, there was slippage between how agents and corresponding resources were identified (with categories crossing over).

Further, students found it difficult to determine the relevance of *virtual* links (information linking users and amenities via apps), versus *physical* links (the physical streets and interfaces that ultimately shaped conditions on the ground). Both links matter but there remained ambiguity regarding how much each should specifically steer the system, and how best to give algorithmic 'weight' to one set of inputs versus the other.

While many of the projects remain at the threshold of our capacities, (such as self-driving or mobile urban amenities), we are approaching a point at which we can begin to think more seriously about how such 'smart' technologies might be used to enhance our static infrastructures. Many of the projects seized upon digital infrastructures and apps as a significant tool with which to help coordinate behaviours. Tapping into the 'wisdom of crowds' (Surowiecki, 2005) was generally seen as a helpful 'system steering' strategy due to the pervasiveness of smart-phones and their capacity to coordinate crowd-generated information signals. That said, this methodology required active inputs - 'ratings and likes' – that might be skewed, particularly as some users of the urban environment do not use apps. Hence, a park bench frequented by the elderly might not receive any positive feedback on an app, but if it incorporated sensors it could relay use patterns whether or not it received active 'likes'.

A further significant observation associated with the projects pertains to how they move away from a 'one size fits all' approach to the urban realm. Agents can be fit whether they cater to a small or large niche. Thus, an agent serving only two people who wish to use occupy a singular floating platform, (perhaps as a fishing dock), is as fit as one serving part of a large aggregated structure of 100 platforms, as it might still only be occupied by two people within a given time frame. In each case 'fitness' is equal, but we now enter into power law dynamics where a host of small niches in the 'long tail' can provide amenities, rather than Gaussian dynamics that cater only to average needs (Anderson, 2004). This capacity to serve multiple niches may provide an escape route from the homogenizing effects of big business control, transferring autonomy to the agent level, and enabling small niches to be served.

Together these projects illustrate a wide range of urban systems that, with some creativity, can be conceptualized as CAS. They reposition the role of the designer such that, rather than providing urban solutions, they instead design urban elements and infrastructures that 'solve themselves' by harnessing CAS dynamics.[40] I hope these thought experiments thereby offer a contribution to ongoing discussions of complex adaptive system research and their implications for spatial planning and strategy.

TOC

9 Sensing the City: Legibility in the
context of mediated spatial terrains

Abstract

Smartphones, with their 'pervasive presence' in contact with our bodies (Leszczynski, 2015),
have come to act as sensory prosthetics that mediate our experience of the city. They activate new
possibilities of navigating the urban, such that we can find exactly *what we want*, rather than *what
has been placed before us*. This paper argues that smartphone technologies produce a more fluid
engagement with urban space: where space is not so much 'given' as 'enacted'. In this context, notions
of 'legibility' (Lynch, 1960) take on new, algorithmic and virtual forms. Thus, where *'the legible city
waited to be **read**, the transparent city of data waits to be **accessed**'* (Hamilton et al., 2014). Here,
stable features dissolve as urban space becomes increasingly fluid and contingent, no longer limited
by static patterns of inhabitation. Instead, *how* we move and *where* we move shifts in accordance
with the kinds of urban resources being activated at any given location, at any given moment, and in
conjunction with the shifting vicissitudes of the crowd. In this context, the virtual (in its technological
definition of cyber enabled or enacted space), mediates and activates the *virtual,* (in its philosophical
definition pertaining to the capacities of an entity that may or may not be manifested depending upon
context). The paper considers the implications of this novel spatial mediation, using an ontological
perspective informed by Complex Adaptive Systems (CAS) theory. CAS considers forms and objects not
as absolutes, but rather as contingent entities activated through interactions.

Note

This paper has been conditionally accepted for publication in *Space and Culture*, subject to minor
revisions. Portions of this paper also appeared in an earlier version, entitled: *'The Smartphone as
Urban Mediator And 'Sixth-Sense': A New Platform For Recognizing And Acting Upon The Signals Of
The City'* co-authored by Sharon Wohl and Sean Wittmeyer and presented at the 14th Meeting of the
AESOP Thematic Group on Planning and Complexity *'Taking Stock of Complexity Sciences: Evidence of
Progress in Urban Planning?'* Held in Bamberg, Germany; Feb 11 + 12., 2016. I am indebted to Sean
for his initial contribution in helping frame ideas that have since been elaborated upon in this paper.

Preamble

*A teenager is visiting Paris for the first time. Numbed by her familiarity with the ubiquitous imagery of
the Eiffel Tower, she barely spares it a glance. She has, after all, seen the landmark many times before -
its presence being fed to her in endless photos, video-clips and webcam feeds. Her only thought is that,
after all the hype, it appears smaller in real life. Her eyes return to her smartphone, which is tracking
the emerging vectors leading to an Indie band's pop-up gig. Her trajectory shifts, and she ignores the*

moving crowds ahead that might, in an earlier time, have drawn her towards the Champs D'Élysée. Instead she follows cues emanating from her phone, heading onto a side-street where an Uber idles. At that moment a push notification sounds, causing her to pause and reconsider her options. She has arrived at a fork in her mediated virtual road. While the pop-up gig remains compelling, she is alerted to the fact that another band is trending at a club in the 18th arrondissement. Weighing her options, she checks the reviews of this new band and makes her decision based upon its ratings which, at that moment, are marginally higher. Typing a quick message, she alerts her Parisian cousin as to her course, and they plot their rendezvous. Her cousin, a well-positioned node in his social network, in turn posts their evening's plans on social media, amplifying the draw to the club in the 18th. The reinforcing feedback loops initiated by this sequence of events in turn pull greater numbers to that site, as his friends tell their friends... Meanwhile, at the other end of town, the other pop-up gig location fails to gain traction. Its niche appeal or 'fitness' is geared towards a similar demographic. Had initial conditions differed slightly – causing the teen's moment of decision to veer the other way - it might equally have manifested as the 'happening' event of the evening; but on this particular night its capacities remain dormant.

§ 9.1   Part 1: The smartphone as bodily extension

I wish to make the claim that the ubiquity of the smartphone as part of our day-to-day lives marks a sea change in how we intuit the world around us. The phones, now carried by more than half the world's population in rich and poor countries alike,[41] are not simply a means of looking up data or staying in touch with one another. For the billions of youngsters who keep their phones with them at all times, (including in bed) smartphones behave as bodily *material extensions* (Ihde, 1975), ones continuously engaged with while navigating through temporal and spatial situations. Admittedly, for those in older generations this extension is not so acute. There are those who still consider the phone merely as a tool employed on occasion to make calls, or to access information once obtained through maps or other sources. But for the generation growing up in the Internet age, the phone is not simply another tool that is employed on an as-needed basis. It is instead a necessary corporal extension – the removal of which (as any parent knows) is considered an impairment to existence. For this generation, *'the iPhone does not feel like a desktop or phone experience, but instead something immediately recognisable as a personal interface to ambient information... embodied by tangible interfaces activating living information in the here and now'* (Bratton, 2009).

For this generation, the phone - with its pervasive bodily contact vibrating notifications, alerting information with its pings – becomes a sensory prosthetic that is relied upon from the moment of waking till the moment of sleep. It imbricates human and machine as co-entities, enabling its users to perceive the world in an intuitive manner that moves beyond the reach of normal sensory apparatuses (Leszczynski, 2015). This extended sensorial capacity highlights previously obscure information, allowing the city to be perceived in new ways. Accordingly, *'for contemporary citizens, the act of reading, filtering, and interpreting the city is increasingly performed by software...in such technologies, the perception and navigation of geospatial volumes often seem to be less a factor than the perception and navigation of screen interfaces and databases'* (Hamilton et al., 2014).

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41   See https://wearesocial.com/special-reports/digital-in-2017-global-overview.

In this reading, whereas, *'the legible city waited to be **read**, the transparent city of data waits to be **accessed**'* (Hamilton et al., 2014).

In this emerging phenomenological context, an emergent 'transparent city' is brought to our attention by an increasing array of Apps that, in turn, steer our day-to-day lives. Here, our real time connection to data about remote environments shifts our sense of personal bounded space, distorting notions of proximity and distance: a bar forty blocks away that we pick up as 'trending' and for which we can source a nearby 'Uber' becomes sensorially more accessible and desirable then a mainstream downtown pub that is just a short walk away. This *'ambient findability' (Morville, 2005),* constitutes a new engagement with the world where, *'information is in the air, literally. And it changes our minds, physically' (Ibid).*

How do we 'sense' our environment within this new context, where the city is no longer a fixed, static entity, limited by rigid forms of inhabitation, but rather a fluid, indefinite entity that modifies itself in accordance with our needs and changing fields of opportunity? Here, the fixed infrastructures designed for *normative* trends of movements become redundant in light of much more nimble and adaptive systems – the Lyfts or Ubers - that have the capacity to quickly enable independently valued flows. In this context, as noted by Nigel Thrift,

'environment' no longer describes a set of static co-ordinates forming a frame within which bodies move but a continually changing tableau in which bodies appear to have motility and which therefore has the ability to redefine itself in real time. The fixed frame becomes a continually unfolding, fluid and convective map of different kinds and rates of movement (2014, page 10).

Within this context, traditional notions of civic legibility need to be at minimum re-conceptualized, and ultimately perhaps, replaced.

This paper will explore these issues in ways that are both grounded and speculative. The research is informed by the use of Complex Adaptive Systems theory as a perspective with which to understand contingent, bottom-up and unfolding processes. These processes have been studied at length by scientists, with their dynamics fairly well understand. This understanding is then extended so as to speculate upon a future where our awareness of the urban is heavily mediated by the smartphone, resulting in a new level of information fluidity with regards to how the city is accessed or 'read', and how this reading then enables new actionable ways of experiencing the urban. Part Two (following these introductory comments) situates the discussion within notions the framework of urban 'legibility' -a notion initially introduced by Kevin Lynch, but one that no longer adequately frames the experience of the urban. Part Three moves on to discuss how Complex Adaptive Systems theory provides an ontological perspective that is able to reframe a new kind of legibility that encompasses shifting realities, while still acknowledging stable (albeit contingent) vectors of convergence. I argue that CAS perspectives reconcile both the multiplicity of seemingly arbitrary and individual agent-based decisions, as well as the emergence of coherent general patterns. Part Four considers potential political implications of this reading of the urban, highlighting how, by being enacted through bottom-up processes, this reading differs from many current academic speculations regarding 'smart' urban futures. Part Five concludes with some cautionary comments, noting that CAS processes can, if left unchecked, potentially generate emergent outcomes that undermine civility.

Kevin Lynch's work on *imageability* has, for decades, served as core to our understanding of how individuals use spatial cues to 'get their bearings' within the civic realm and navigate within that context. Lynch's *Image of the City*, (1960) identified key urban features - landmarks, paths, nodes, districts, and edges – that provide visual cues with which people mentally map their location within the greater urban context. Part of this navigation entails an understanding of spaces that exert 'pull' by affecting the senses through their hierarchical signalling: a tower situated against a neutral backdrop draws us in, an open space within a dense urban network causes us to pause within the specificity of that node, a strong edge suggests a boundary that may feel threatening to cross. Thus, we attribute places that signal *difference* – those marked by visual scale or other forms of visual hierarchy - as being special moments within the urban fabric. Similarly, our visual sense of boundaries (Lynch's Edges) helps us to define regions that we regard as either 'inside' our territory, or 'outside' and belonging to the other. Our tendency is to remain within the charted territory of 'insidedness', gravitating towards places that 'announce' their significance within this territory through visual cues.

This structure of these overall urban patterns steers individual decision-making at the local level. Physical cues, as they impact our senses, affect whether one turns left or right at an intersection, whether one crosses a threshold or veers away from it. As we scan the environment, the presence of boundaries like major roads or rivers, the perception of landmarks like towers in the distance, or the convergence of movements towards a node, each exert a slight gravitation or repulsion that, all things being equal, will draw us towards particular trajectories that are generally *shared*. Consider, for example, the location of urban commercial attractions. Traditionally, the discovery and draw of businesses has been connected primarily to their location, with bars, restaurants, and clubs being situated in busy economic zones near cultural hubs or attractions. People tend to gravitate towards these consumer-centric economic areas of the city, and businesses vie for locations in close proximity to these zones. Prime business sites tend to cluster near Lynch's Landmarks or Nodes, where individuals 'naturally' gravitate in response to the way-finding cues these spatial anchors provide.

The ability of such physical cues to steer our behaviour is predicated upon them holding a significant enough perceptual weight in the civic landscape to garner our attention, with this 'weight' traditionally being associated with contrasting visual presence. This factor puts restrictions upon the number of actors able to leverage this presence: only those players with sufficiently large pocketbooks tend to exert significant physical manifestations of their presence within the broader sensory realm. At the same time, these large-scale actors tend to market themselves towards the most neutral demographic possible: *appealing to the average and the normative* (witness the dominance of big chains). Accordingly, the numbers of urban offerings that are reliably perceivable are those appealing, for the most part, to the generic.

But if people's sense of orientation within space has traditionally been guided by clear and consistent physical cues that are perceived by all, we now seem to be entering a phase wherein these *physical* cues are being subsumed by *virtual* cues. In this scenario, new viable options of orienting oneself in space are created. Lynch's paths, for example – which have an inherent hierarchy that directs our sensorial choices - are now traced not through visual orientation, but through app systems that might, for example, steer our attention to *particular* pathways based upon real-time information about congestion, noise levels, distance comparisons, etc. The data associated with highlighting these pathways is not static: it can change over the course of each day and, rather than defaulting to the accreted hierarchy of past patterns of occupation, be accessed and customized such that it responds

to an individual's particular preferences.[42] In this reading, Lynch's principles take on *'new, algorithmic and virtual forms'* (Hamilton et al., 2014). Furthermore, these algorithms need not be generic, but can be individualized in accordance with the patterns exhibited by one's friends, one's past route choices, or one's recent searches.

While Lynch's formal indicators have, for decades, provided a clear and stable means of framing our understanding of the various manifestations of the urban fabric, his concepts are no longer helpful in guiding us through this expanded terrain, where space perceptually manifests as an individually curated experience - steered by virtual signals and indicators attuned to individual preferences. The presence of Lynch's landmarks, nodes, districts, all evaporate as stable delineators and are replaced with much more contingent, variable and customizable offerings.

How might we then frame an ontology that captures this new environment, and an epistemology that resonates with our augmented sensing capacity as we navigate within it? I believe that in order to appreciate the impact that an expanded sensorial awareness brings to the city, it is necessary to move outside an object oriented view of the city - one that considers civic environments as static entities that are stabilized in space and can shift only slowly in time - to instead consider cities as dynamic systems in non-equilibrium: ones that constantly evolve with their users and are constituted by fluidities of changing densities and kinds of information. This perspective suggests that the presence of the smartphone as a mediating agent calls forth a less static view of space - something that is not so much 'given' as 'enacted'.

The next section will outline how Complex Adaptive Systems (CAS) theory can provide distinct conceptual tools with which to grasp and frame this shifting perceptual landscape. CAS understanding is predicated upon an ontology that sees the world as constituted not by fixed objects, but rather by shifting and contingent relationships. Accordingly, the next section will introduce key CAS concepts that might be used to conceptualize urban perceptual features.

§ 9.3   Part 3: Introduction to Complex Adaptive Systems

When ants are seeking food, they have no signposts with which to guide them. Nevertheless if, on a warm summer day I leave some breadcrumbs out on my counter, and if there is a small hole in my screen window, then after a period of time I will see a regular trail of ants marching along the countertop, heading towards the crumb. In the ant world the crumb is a *Landmark* to which the ants have clearly formed a *Path*. Equally evident is the transitory nature of the path: it only exists as long as the crumb is there, and there are no fixed demarcations used to frame it. Further, while the ants are able to successfully march in the direction of the food, they have no broader cognition of what they are doing. No ant is in charge of ant directing the system. Here we see a classic example of the dynamics exhibited by Complex Adaptive Systems. CAS are systems that: involve many agents (such as ants); foster interaction or information exchange amongst these agents (in the ants, through the release of pheromone signals when food is present); and enable the emergence of global patterns (such as ant

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trails). Stable structures like ant trails emerge despite the fact that the agents involved in creating this pattern are acting only in their own self-interest and have no broader conception of the patterns they help co-create. That said, once stable patterns emerge, these in turn exert agency in a recursive process that influences subsequent agent interactions (through reinforcing or 'positive' feedback).

CAS are *complex* in that the dynamics of the system operate in a non-linear fashion: a small change in initial conditions of the system can lead to wildly divergent outcomes in terms of the behaviours that the system ultimately manifests. Thus, if I have two breadcrumbs at different ends of the countertop, the initially random trajectories of a few ants may cause one crumb to be discovered first – whereby pheromones will be deposited leading towards that crumb, creating feedback loops that result in a trail heading towards that crumb versus the other. Here we observe that, unlike systems governed by Newtonian dynamics, the overall behaviour of the system cannot be accurately predicted based upon linear assumptions where effects are proportional with causes. That is to say, a small, random, initial cause (one ant initially turning left versus right) may result in a disproportionately large global effect (a significant pathway leading towards one crumb versus the other).

CAS are therefore understood as having the capacity to unfold in a number of divergent *contingent* trajectories, with the trajectory that ultimately manifests being predicated upon historical circumstances. Here, 'prediction' is relegated to: learning about the potential *range* of trajectories (or 'phase space'); the kinds of behaviours that have a *tendency* to play out ('basins of attraction'); and the ways in which behaviours are structured or *steered* ('evolutionary processes').[43] Further, the environment (which includes the trail being formed) in which the agents operate is both a *result* of agent interaction, and a *factor* that predicates and constrains subsequent agent interaction in an ongoing dance of agent/environment co-evolution. Finally, CAS behaviour is effectively steered from the bottom-up versus the top-down. As such, CAS research requires a shift in how we think of effective organizations, given that highly 'fit' and tuned behavioural patterns are able to emerge without the top-down organizational control we tend to associate with generating efficiencies.[44]

Given these dynamics, my core thesis is that the smartphone, as a mediating interface, enables CAS processes to unfold through its ability to coordinate the actions of many individual agents, broadcast signals, allow for feedback processes, and thereby foster emergent civic dynamics. Here, the shift towards citizen-sensing enables the transition from a linear system of data collection – that essentially involves action and reaction - to a much more nebulous and complex system. Not only are normally invisible caches of urban amenities highlighted through the amplified sensory capacities of the smartphone, but offerings that emerge as popular can subsequently generate reinforcing feedback loops - altering the emerging data-scape and thereby the perceived cityscape. Such rounds of feedback loops amplify initial slight signal variables, resulting in the fact that subtle shifts can now cause hugely divergent urban actions (following non-linear trajectories). Consequently, in this new 'sentient city' (Thrift, 2014), 'an awareness starts to arise which invents the means to submit to its own requirements, to activate its own activation' (Ibid: 12).

Instead of the stable equilibrium of the 'downtown business district' or the central square and plaza, CAS allows us to think of the space of the urban as occupying a multitude of potential points of

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43   Each of these terms are commonly used in discussing CAS and are fully discussed in other publications. Examples include: for 'phase space' (Batty and Torrens, 2005); for 'basins of attraction' see (Kauffman and MacReady, 1995); for 'evolutionary processes' (Heylighen, 2000).

44   A full overview of CAS lies outside the scope of this paper. The interested reader can consult (Heylighen, 1999b; Holland, 1995; Kauffman, 1996)

attraction in a fluid space of contingent potentialities, a 'phase space' that congeals and thickens at particular locations in particular moments in time (Jones, 2009). The notion of phase space refers to the overall 'space of possibilities' that a complex system might explore or occupy. We can think about mapping this phase space in terms of a system's 'degrees of freedom', or the number of variables that comprise the system (as well as the boundary conditions for these variables).

For example, we might imagine a scrabble-board that we are able to overlay with tiles in a random pattern. We could permit pieces to be placed anywhere along the length of one row on the board (one degree of freedom) or extend the placement possibilities to include all rows along the height of the board (two degrees of freedom), or extrude that to include the vertical space occupied when tiles are stacked on top of one another (three degrees of freedom). Additionally, given that tiles are imprinted with letters, we might also select which letter will be displayed in any given position, (four degrees of freedom). Each degree of freedom has its own range of limits or boundaries. Thus, the number of squares (on the x/y axis) of the board creates limits, as does the viable stacking height (perhaps before the tiles fall), as well as the range of possible letters (A-Z). Thus, while the overall phase space of possible placement configurations is bounded, it still offers an almost infinite range of potential manifestations. That said, in many instances, particular *patterns* of occupation are more likely to occur within phase space than others. That is to say, phase space may have differential 'attractor states', or 'basins of attraction', but the specific way in which trajectories of occupation are manifested are contingent, being subject to historical circumstances.

Furthermore, the actions initiated by agents in complex systems, even if initially somewhat arbitrary, have the capacity to generate feedback loops that result in non-linear amplifying effects. In this way, historic circumstances shape trajectories within phase space, calling forth certain outcomes while glossing over others that may, in fact, be equally viable. Here, the choice of an agent to turn left or right, to build upon one plot versus another, or (as in the case of our teenager) to patronize one club versus another, while initially arbitrary can nonetheless produce a chain reaction of amplifying effects. To illustrate further, the decision of a patron to dine at one restaurant versus the one next door makes that restaurant looks busier than its neighbour – sending a signal which perhaps implies that it has better food - which in turn causes it to be more appealing to the next set of customers, which in turn makes it look busier, which attracts more customers, etc.

I am arguing that the smartphone amplifies more of the latent enactment possibilities of the urban: allowing resources that were always present but 'under the radar' to be accessed, activated and amplified. Accordingly, new trajectories in phase space – new degrees of freedom – are made sensible and thereby viable. But the system does not stop there. Once a new trajectory has been sensed and occupied, its gravitational 'pull' in phase space is incrementally amplified, sending out a stronger signal. This amplified signal reaches new users, and a feedback loop ensues. As users of the urban sphere are drawn towards a particular basin – pulled in by the gravitation of signals not previously sensed – the gravity of that site grows stronger. Whether this basin of attraction comes in the form of a bar, a café, a flash mob site, or a plaza, its emergence as a 'weighty' niche within the urban fabric is now no longer predicated upon its static position within a pre-determined hierarchy. Instead, these basins of attraction, whether nodes or landmarks or pathways, emerge out of the phase space of potentiality, iteratively reinforced by individuals whose actions are both steered by virtual signals and subsequently generate same.

Further, these virtual signals can be modified so as to pick up highly tuned signals regarding how well a trajectory fulfils various *individually* desired outcomes. Airbnb provides a case in point. Certain rentals tracked by the popular website may emerge as prime attractors for travellers for whom location and price are the top priorities, whereas other locations might be a preferred draw for those who favour

privacy and cleanliness. By partitioning such divergent 'criteria for success' into discrete parameters we are able to decompose urban offerings such that specific, individualized optima can be located within the overall phase space. This bracketing of the available phase space trajectories considers only the degrees of freedom relevant for each individual. Again, to illustrate - the optima for finding an ideal co-work space might involve a range of individual preferences with regards to rental costs, overall square footage, functional amenities, proximity to transit, number of workspaces, etc. Here, the larger the number of discrete parameters (or degrees of freedom) available to inform decision-making, the larger the navigable phase space, or the more potential 'niches' for occupation. As individuals hone in upon each of these parameters, specifying the range of applicability and priority granted to each, the viable area of the territory they wish to *specifically occupy* within phase space becomes highly tuned. In an era where smartphones are able to match specific urban niches with specific user parameters, highly discrete niches of occupation become viable, even if their location in phase space are only optimal for one individual. The smartphone, makes the information associated with each point in phase space - its corresponding specific characteristics - fluid and 'findable'.

§ 9.4   **Part 4: New Trajectories of Possibility and of Power**

It is worth framing the above in relation to the ontological assumptions of complex systems as outlined by Manuel Delanda (2005, 2011). Delanda has been instrumental in detailing the differences in a given entity's *properties,* (which are inherent to the object, regardless of any interactions it is brought into) its *capacities* (which are manifested or brought into being only when entering into relations with other entities) and its *tendencies* (which, like attractors, are capacities that an entity is most likely to manifest). To illustrate, we can suggest that a hammer has properties of weight and shape, but that the capacity for this weight to be used to drive in a nail requires that the hammer enter into an assemblage where it is wielded by a human agent. Further, we can state that while the hammer's weight could equally be used to slay a victim, though this capacity is not a general tendency. Delanda writes,

... since neither tendencies nor capacities must be actual to be real it would be tempting to give them the status of possibilities. But the concept of a possible event is philosophically suspect because it is almost indistinguishable from that of a real event, the only difference being the former's lack of reality. Rather, what is needed is a way of specifying the structure of the space of possibilities that is defined by an entity's tendencies and capacities. (2011: 5)

It is this space of possibilities that physicists describe as 'phase space', and which Delanda (following Deleuze and Guattari), describes as 'the virtual' (DeLanda, 2005). While the world a*s lived* actualizes along specific trajectories, the same *virtual* space can support a multiplicity of equally viable trajectories. Philosopher John Protevi writes, 'here we should pay attention to the coexisting non-actualized (i.e., virtual) attractors' (2013, page 3). Acknowledging the viability of the unrealized virtual, (and at the same time the contingency of the manifested actual), moves us away from thinking about reality in stable ways. Protevi, notes that the virtual illustrates how,

... we live in an open, problematic world, as shown by the non-linearity of causes and the complex affects they give rise to and by the non-linearity of models which include multiple attractors. Thus we see that in Deleuze's world, as reconstructed by DeLanda [...] history matters but the future is open. (Ibid: 5)

CAS, by conceptualizing forms and objects not as absolutes but rather as contingent entities activated (or remaining dormant) as a result of interactions, provides an ontological perspective that can accommodate this virtual terrain. Here, urban entities are positioned as potential basins of attraction, never stable or permanent, but rather as having the capacity to manifest according to feedback dynamics. By recognizing the presence of contingent and historical dynamics, this ontology redirects our attention so as to attune not only to the 'real' trajectories that unfold, but also to those that are equally viable (and remain present in phase space), even though they did *not* unfold.

In this reading, the manifestation of a specific trajectory of action (such as one that might popularize a particular node such as an urban plaza), departs from focusing only upon the node or plaza *in and of* itself. Instead, it is both the potentialities of this urban element - its latent 'capacities' – that matter as well as how these come to be activated or brought into being by other agents. In this way, the topography of phase space, while showing all range of capacities, is still variegated enough to highlight a system's tendencies. Clearly, some plazas will be better positioned to serve the public than others, and accordingly not all plazas that hold the *capacity* to become popular, will also have the *tendency* to become popular. But a CAS ontology orients us to the fact that even though one plaza may be more popular that another, this is not inherently due to a clear-cut cause and effect relationship, where proportionate popularity is solely the result of proportionate causes. To say that a 'plaza' is popular (situating the identity of popularity within the plaza in and of itself), is therefore inaccurate. Instead, the plaza/human imbrication or *assemblage* is what is productive or activated at a certain time, and a *specific* plaza's activation is highly contingent: depending *both* upon the inherent capacities of the plaza, but *also* to the historic circumstances that may have resulted in feedback which stabilized the plaza as a popular node.

What is interesting about the advent of the smartphone as a ubiquitous feature of our lives, is that it brings new dynamics to bear upon how trajectories in phase space might unfold. It enables us to find and activate capacities of urban interactions: ones that may have always enjoyed a virtual existence, but because of the constrained information channels within the system did not have the *tendency* to actualize. In the past, the threads that wove together agents in space and the kinds of spaces they occupied were bundled together along very specific trajectories – those that were reinforced through habit or through power. This posed a limit on the control parameter of the system, capping off with only a number of limited regimes made accessible.

But the smartphone redistributes these threads in novel ways. In this city, it is not the only the key agents, the 'big brands' that dominate our senses. Rather, the 'long tail' (Anderson, 2004) of customized urban possibilities are revealed to us - made sensible - in ways never before imagined. This has significant social implications. Rather than being gripped by normative values that shape how a city is 'supposed' to be experienced and lived, individuals are given the means with which to curate their own course. Power is shifted from the top-down to the bottom-up.

Further, the expansion of our normative boundaries to include sites previously unsensed and unseen permits us to navigate outside of familiar, geographically bounded settings. Here, 'insideness' is no longer defined by Lynch's geo-spatial boundaries of edges, but instead exists as an individually curated expanded spatial field. We determine the geographies that matter to us. We decide if we wish to navigate along quiet routes or beautiful routes or fast routes, and we decide which nodes of spatial resources we wish to navigate towards. Our boundaries may remain parochial, but it is a parochialism that we each define for ourselves, and which stretches, distorts, and occupies phase space in unique forms and imprints for each individual. Rather than being seized by the normative geographies of top-down power, we are given the sensitivity with which to grasp and make manifest our own city.

It is worth highlighting this emancipatory potential of bottom-up, technologically mediated experience, as this perspective appears to be largely absent in the larger body of 'smart city' critiques that have recently proliferated in academic discourse (Ash et al., 2015; Halpern et al., 2012; Kitchin, 2014). These critiques are highly attuned to the risks of a panoptican society, where everything we do is monitored in the efforts to generate big data that is analysed and used for purposes of civic 'optimization'. Clearly, this dystopic vision is something that should be highlighted and guarded against. But at the same time, by only highlighting the risks of technology, other, more democratic means through which technological innovations might equally manifest have perhaps been overlooked.

For every expression of concern regarding monitoring, we might thus point to examples of technological mediation that are empowering. Scholar and activist Jeffrey Juris, for example, observes how smart devices were implicated in directing his actions during the #Occupy Boston movement. In orienting himself in space, he describes how, '*my Android phone indicated a large group of protesters was on its way from the #Occupy Boston camp at Dewey Square and would soon turn a nearby corner… minutes later… I eagerly jumped into the crowd and joined in chanting*' (2012, page 259). In addition to steering such physical actions, images and tweets of activist events were captured on smartphones and circulated via social media, helping mobilize further activism in ways that the mainstream media (which authoritarian governments can manipulate in order to limit what is 'sensed' by the public) could not do.

In this more optimistic, emancipatory reading, we are empowered to diverge from the norm, the 'central path', and instead construct the path that serves our immediate needs. Furthermore, we are led to discover regimes that may be popular for many others, but that previously existed only as latent potentialities. These constructs – possibilities in phase space – while always present, were mute with regards to our ability to perceive them, trust them, and draw upon their latent capacities. The smartphone brings with it the capacity to weave together different locations, persons, and times, binding together the complex civic system at the node of the personal body. But the web it weaves is tailored for each individual, with threads of connection carrying different weights and thicknesses dependent upon the nature of the individual, their propensities and their preferences.

§ 9.5   Conclusion

The capacity to sense the city at a distance, to detect patterns and, by our actions, to modify and shape these patterns, opens up fundamental changes in how we conceptualize and analyse the urban. In this reading, the city is not so much 'given' but uniquely sensed, enacted and experienced in multiple, overlapping, and individual 'satisficing' scenarios - each of which are contingent upon the moment in time, the actors involved, and the discrete selection of which urban signals are privileged.

How might we grasp this new form of urban experience, one that is no longer so tightly bound up with the physical constructs we are so accustomed to focusing upon? If we normally rely upon *mapping* (in both physical and mental forms) to help us understand urban dynamics, then how might we map this urban terrain? And what would this map contribute to future analysis, since the paths, landmarks, and nodes it captures would remain so tenuous and contingent in their manifestation? Further, if this conceptual space is populated not by inherently stable entities but instead by contingent virtual affordances, does this then negate the possibility that stable basins of attraction nonetheless emerge?

Or will the urban system, with its enhanced capacity to reveal a broader range of spatial trajectories, discover unexpected and emergent patterns of occupation and engagement that are reinforced and proven 'fit' over the longer term? Will co-evolving individual experiences result in emergent shared realities (such as when the actions of individual birds in a flock result in the coordinated movement of the whole), or will they remain discrete, with the urban experience splintered into multiple overlapping and co-existing realities?

CAS would suggest a rich array of the above dynamics. The information cues generated by individual experiences become signals that play back to other agents in the system, in turn modifying both the nature of the urban, and the possibilities of action within it. But it is unlikely that this will lead to a unified, global outcome in the system as a whole. Rather, different kinds of urban amenities or activities will tend to attract different kinds of users. We can imagine a sort of 'niche urbanism', with user-specified niches emerging and co-evolving with their population of users. One might argue that these parallel urbanisms already exist, as different socio-economic realities construct cities that present dramatically different kinds of urban experiences. But the difference here is that these realities are not currently conceptualized in a manner that implicates the individual as their point of origin. A CAS ontology, by contrast, outlines the ways in which such emergent urban niches can manifest from the bottom-up.

That said, CAS tells us nothing about the values associated with these niches, nor does it offer us any assurances that different niche realities will intersect in complementary ways. Network theory (a subject which lies outside the scope of this paper) can perhaps lead us to a better understanding of the dynamics whereby niches might overlap and intersect through bridging nodes, rather than becoming strongly segregated from one another. This points to a key political issue. If niches fragment into isolated enclaves – the 'echo chambers' that have sprung up in our Facebook feeds - they will, while doubtless appealing to our *preconceived* preferences, seldom challenge or expand them. Left unchecked, this sensorial echo chamber can be self-curated so as to reinforce parochial perspectives and propagate prejudice.

By contrast, Lynch's Landmarks and Nodes have held the promise of serving as public attractors for all: fulfilling a social and political role that brings different populations and perspectives together, shoulder to shoulder.[45] If a sensorially mediated urbanism serves only to reinforce and amplify differences it would indeed be dystopic, albeit a 'bottom-up' dystopia that differs from the top-down panoptican models that are currently being cautioned against.

While this paper attempts to outline a more optimistic perspective on the potential of smart media in our lives, I am well aware that this perspective may appear naïve to those who remain sceptical to claims that technologies will solve our problems. Notwithstanding this critique, the role that the smartphone as an extended sensory technology will ultimately play in our lives is far from evident. Choices we enter into now may lead us towards a technologically mediated world that monitors and steer us, or one that we are able to control and configure in accordance with our own needs. It is not yet evident which of these potentials is more likely. Perhaps, both are equally viable potentials in the phase space that extends before us. If history provides us with lessons, these only serve to indicate that we are poor forecasters of where innovations will ultimately lead.

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45   The role of 'bridging nodes' - the 'third spaces' where different communities can come together, is a topic I consider in depth in the Coda to this dissertation. While that paper does not engage CAS directly, it does discuss the important political role these kinds of nodes play.

What is evident is that smartphone technology is here to stay, and that our corporal bodies are becoming increasingly bound up within its new capacities. Their full impact upon our sensorial lives has yet to be clearly understood, but clearly Lynch's 'sense-making' urban categories will no longer adequately encompass the range of urban experiences he outlined in *Image of the City*. Lynch's coherent images will shift out of focus, taking on multiple, unique overlays, only some of which will be intersecting and reinforcing. Our perceptions of what constitutes a landmark, edge, node, path, and district will become increasingly customized and the cities they lead us through increasingly fluid and contingent. Hopefully this will lead us closer to grasping the city we want - that fulfils our own desires and curated needs - rather than the city that is placed before us.

PART 5 Conclusion

10 Conclusion

§ 10.1 Summary of Research Objectives

In order to summarize the Ph.D. research, I would like to reiterate the core question that I outlined in the introduction:

What physical and morphological conditions need to be in place within an urban environment in order for CAS dynamics to have an opportunity to arise - such that the physical components (or 'building blocks') of the urban environment have the capacity to discover functional configurations in space and time as a response to unfolding contextual conditions?

In order to answer this question, I set out to:

A *undertake a detailed examination of the key dynamics associated with complex adaptive systems that allow these to hold emergent, self-organizing and evolutionary capacity (regardless of the system under study);*
B *identify the corresponding physical characteristics that need to be present within the urban morphological setting in order to instigate the unfolding of similar dynamics;*
C *formulate and corroborate a clear analogical appropriation of CAS theory that illuminates the basic requisite requirements for physical urban environments to function as Complex Adaptive Systems.*

In order to make this question useful for designers, I aimed to:

D *offer a conceptual framework that makes the principles of urban CAS dynamics more understandable, intuitive, and operational for Urban Designers.*
E *demonstrate how this formulation might be employed to steer design processes, whereby designers create 'potentialities' rather than designs, and steer or instigate - rather than control - dynamic urban processes*

§ 10.2 Summary of Research Conclusions

In all instances of CAS, certain critical components need to be present in order for evolutionary emergence to occur. Understanding which components need to be present was therefore imperative to advancing the research. In answer to my objective **'A',** I therefore:

A *undertake a detailed examination of the key dynamics necessary for CAS processes to manifest in urban situations.*

This examination concludes that the following key attributes need to be in place for CAS systems to evolve **[see Figure 10.1]**:

- The presence of many agents – small enough to be nimble and explore many states
- The presence of differential flows within the system that create differential states which agents can respond to.
- The presence of signals (tags or stigmergic signals) that leave traces within the shared environment of all agents, such that they may be directed towards preferential flows or energetic differentials: this in turn creates feedback conditions.

With these attributes in place, there will be the tendency for the following two phenomena to manifest:

- The emergence of attractor points: concentrated areas where many agents converge
- The emergence of stabilized patterns (districts or assemblages): broader regions that encompass a collection of agents organized by networks of both larger and smaller attractor points, but in configurations that become stabilized and resilient.[46]

With these pre-conditions for CAS identified, I am able to address objective **'B',** where I:

B *identify the corresponding physical characteristics that would need to be present within the urban morphological setting in order to instigate the unfolding of similar dynamics.*

By analysing a variety of precedent examples, including existing civic districts, projects currently under development or proposed by others, projects speculated by myself or by my students, I gather together a variety of examples of the kinds of urban organizations and morphological conditions that can be seen as meeting the characteristics described above.

Considering these cases together, while being mindful of both EEG and CAS techniques, I am then able to formulate a synthesis of the kinds of urban features that enable CAS dynamics to manifest in urban settings. This then leads into objective **'C'** where I:

C *formulate and corroborate a clear analogical appropriation of CAS theory that illuminates the basic requisite requirements for physical urban environments to function as a Complex Adaptive System.*

By framing my understanding of CAS through an urban classification system provided by Lynch, I endeavour to meet objective **'D':**

D *provide a conceptual framework that makes the principles of urban CAS dynamics more understandable, intuitive, and operational for Urban Designers.*

I test this framework through the analysis of the Grand Bazaar, to see if it can be used as a way to better perceive and understand the processes that occur in that environment. In order to corroborate the

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46   It should be noted that the difference between an attractor point and a stabilized pattern (or assemblage) is largely dependent upon the level of system being examined. While a particular attractor point - say a web page on urbanism in Wikipedia - is an element within a broader stabilized pattern which is Wikipedia, Wikipedia itself is an attractor point within the larger stabilized pattern which is the World Wide Web (itself an attractor in a broader pattern of infrastructural interfaces). This reflects the idea in Complex Systems Theory that complex assemblages exist within nested hierarchies, where the 'agents' of one system are themselves the result of agent emergence at a lower level. In urban terms this means that houses might be the agents that compose a district, districts agents that compose a city, and cities agents that compose a region….and so on. In all CAS a first determination needs to be made as to what level of system is under analysis.

framework's efficacy, I simultaneously employ the methods of EEG analysis, to see if similar dynamics are read within both frameworks.

CELLS/AGENTS:
Is the scale/malleability of the urban grain conducive to iteratively exploring multiple program manifestations?

PATHS/NETWORKS:
Are flows uninterrupted, and are there flows of different types, intensities, redundancies? Is the network that supports flows responsive and adaptive?

EDGES/INFORMATION:
Is the viability of use/program made transparent through signals in the environment? How strong/reliable are the signals?

HUBS/ATTRACTORS:
Are there neighborhood areas where similar flows can coalesce into nodes? Are there district level areas where diverse flows can merge as landmarks?

DISTRICTS/EMERGENCE:
Is the emergence of functionally synergistic or complementary program elements manifested?
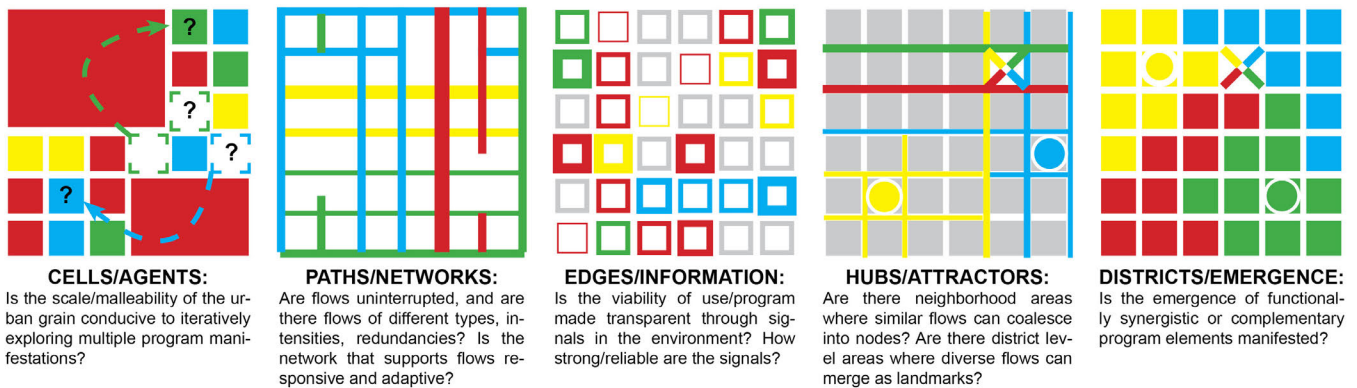
FIGURE 10.1 Analyzing/Designing the Urban Fabric as a Complex Adaptive System

Finally, I wish for this work to be useful to designers, young practitioners, and students. Too often theorists speak in broad terms about theory without demonstrating how theory can be operationalized in practice. This brings me to my final objective, '**E**':

E *demonstrate how this formulation might be employed to steer design processes, whereby designers create 'potentialities' rather than designs, and steer or instigate - rather than control - dynamic urban processes.*

Often, theorists speak in broad terms about theory without demonstrating how theory can be operationalized in practice. As someone engaged in practice, I am interested in the applications of theory. The framework **[Figure 10.1]**, used to examine the Grand Bazaar as a Complex Adaptive System *after the fact,* can also be used as a design tool when planning *new* urban design interventions. Thus, it is important to emphasize that, with an understanding of these attributes, one is not only able to analyze what is present (or missing) within an environment that might foster CAS dynamics, one is also empowered to initiate new urban intervention projects with these dynamics in mind.

Several design strategies become important when using the Lynchian/CAS framework as a tool. While the diagram above summarizes some of the key issues for each urban features, these can be drawn out further. Thus, in accordance with the framework above, when designing to foster CAS dynamics, it is important to:

— Determine the minimum appropriate scale of urban units able to accommodate multiple programs within the context that is being worked within;
— Ensure that 'parallel' urban units are able to test programs independently of one another and individually calibrate the best 'fit' within a given context;
— Enable urban units to be altered with ease - provide them with sufficient morphological flexibility;
— Design urban units such that they have the capacity to merge/agglomerate with other units in a variety of novel configurations (as for example, occurs with the individual Amsterdam canal house floor plates);

- Create redundancies in street networks that allow for multiple kinds of flows to be steered along different courses with ease;
- Evaluate the richness of flows in a given urban environment: if no energy flows are present to 'drive' a complex system, then no evolution can occur. It is therefore important to determine where flows are being directed, where they are blocked from reaching 'dead' neighborhoods, and how they might be better supported;
- Ensure that the urban surfaces operate in ways that allow them to become information rich - this information can take a range of forms: street windows showcasing products, pathways indicating preferred trajectories along fields, gardens showcasing which plants thrive, etc. The important thing here is that the visibly shared surfaces of the city in some way serves as a repository of information that can benefit all, by highlighting content that may be of value in steering urban behaviors;
- Establish areas of convergence, for both local and global sources of information. While information can be transferred across urban surfaces, information can also be conveyed through face-to-face contact. But this only happens when the urban sphere provides the physical settings for flows of ideas to converge.
- Anticipate the emergence of unexpected synergies and urban manifestations. While designers often aim to direct the future, in a CAS design process it is more important to set the process in motion and then let unexpected futures drive themselves forward.

§ 10.3   Broad Research Contribution

In this work, I have undertaken a thorough reading of the scientific literature surrounding CAS systems in order to unpack the internal processes that allow complex systems to display emergent properties. I set out to provide a way of thinking about CAS processes in cities and offer a framework that can serve as a new conceptual lens for both urban analysis and urban intervention. The efficacy of this framework cannot, at this time, be measured. Notwithstanding this limitation, the research does provide an alternative to other frameworks currently being used, which may or may not be more productive. I believe that the framework I offer, while not 'proven' in any way, is none the less grounded – it is informed by an understanding of dynamics of systems as they are conceptualized within the scientific community. The framework I offer, while seemingly a stand-alone offering in the field of urbanism, shares many similarities with modes of analysis used in Evolutionary Economic Geography. Again, I hope that this grounding of my speculative research in the work underway within other domains acts as a form of corroboration for the approach.

This is not to make the claim that building upon so-called 'scientific' knowledge does, in and of itself, substantiate claims made within the humanities. Rather, what I wish to argue is that the framework I offer is not independently generated, but is anchored by findings in another domain (EEG) where it has proven useful. Accordingly, the case study of the Grand Bazaar in Istanbul, being tethered by both CAS principles and EEG methods, offers empirical support to the notion that the built fabric can operate as a Complex Adaptive System. For the most part, such empirical support for urban CAS is found only within the domain of 'objective' computational models, but, as discussed earlier, such models have their own limitations - including the degree to which the model assumptions accurately reflect reality. By providing an analysis of CAS that is situated in the real world, the work intends to offers another means by which urban CAS phenomena can be considered in a more empirical manner (providing an alternative to modeling).

Further, the work offers a contribution to urbanism and CAS theory by considering CAS dynamics in a much more concrete manner as compared with other methods of considering 'on the ground' dynamics. Assemblage Geographers, for example, also aim to understand the situated nature of CAS in urban situations, they lack a clear methodology for going about this. They recognize that urban forces come together in complex ways, that material settings matter, and that these can enter into new relations that then take on agency and emergent characteristics. That said, there is an overall vagueness concerning how one would go about performing an analysis of how things actually unfold. Accordingly, Assemblage Geography has been the subject of critique due to these vagueries (Storper and Scott, 2016). The tools set forth in the Lynhian analytical framework, are able to mitigate some of these vagueries.

Finally, the work provides an alternative to 'forecasting' urban solutions. While work in Communicative and Strategic Planning adopts the language of CAS to try to better steer the planning process, this process is still aimed towards generating more informed forecasts of desired urban futures. This work, by contrast accepts the future as unknowable, but nonetheless provides ways in which to accept uncertainties, while simultaneously planning for change.

§ 10.4   **Further Relevance**

Beyond responding to the questions laid out at the outset of the Ph.D., some aspects of the research have become relevant that contribute to a variety of other research agendas, as outlined below.

A   *Clarify the multiplicity of approaches that engage CAS in urbanism*
Over the course of working on the Ph.D. I have been exposed to a plethora of different approaches whereby urbanism and planning engage complexity. It becomes clear when reviewing the literature that the field suffers from researchers speaking at cross-purposes – not understanding the terms and concepts that are advanced by different streams of inquiry that each try to engage with different aspects of complex systems. I have endeavoured within the literature survey to disambiguate how different streams of urban inquiry draw from CAS principles in different ways. I hope that by illustrating the relationships between different fields and different streams of CAS, this component of the research may contribute to more productive intra-disciplinary dialogue. By providing a set of the six generalized CAS features derived in Chapter Two, this work can thus support existing research agendas - clarifying their scope, their gaps, and their potential overlaps.

B   *Respond to other formal planning approaches (particularly New Urbanism)*
Though central to my primary objective, this research can offer a contribution to North American planning debate insofar as the merits of New Urbanism is concerned. New Urbanism is part of the Post-Modern Classical reaction to modernist architecture that erupted in the late 80s. While this stance only briefly influenced architectural practice, it is still playing a key role in shaping design ideas at the urban level, particularly in North America. Here, NU remains highly influential as a planning strategy, with the teaching of New Urbanism prevalent within urban design programs. With little else to challenge modernist planning doctrines, many North American planners have embraced New Urbanist strategies in an effort to emulate the successful models of the past. While this approach has been the subject of no shortage of scholarly critique, the section on New Urbanism within this dissertation frames the critique in a novel manner. It argues that the successful precedents NU emulates were often not planned, but instead arose as a result of incremental processes of testing,

adaptation and retention. Hence, the critique argues that NU's premise falls short, in part because it does not acknowledge the critical component of process when it attempts to codify form.

C *Contribute a morphological dimension to the EEG discourse*

Evolutionary Economic Geography is an existing body of research that endeavours to understand how CAS processes are critical in shaping geographical regions. That said, this emerging body of research does not yet contain a robust discourse regarding the material dimension of the environment wherein economic unfolding occurs. This work, therefore, expands upon the current EEG discourse. It does so by framing the ways by which the material fabric wherein economic processes unfolds is not neutral. Instead, this fabric can affect the ability for latent economic forces to be realized. This relates to the notion of 'phase space', which is understood in Economic Geography as being the space of possibility within which economic activities can unfold. But it is also true that these economic activities occur within physical settings: that the 'design space' for these activities has a bearing upon what can and cannot occur. In a time when we are faced with dead malls, boarded up small towns, and the proliferation of big-box stores, it is worth asking ourselves how decisions made at the urban design level affect what is able to unfold at the economic level. This is not to suggest that design can, in and of itself, be a solution to broader economic woes, but that it can have a bearing on what occurs by either enabling or thwarting certain economic solutions. If there are no spaces for small actors to gain a foothold, then the economic landscape cannot effectively support the exploration of novel or niche markets. Accordingly, the tendency to build in large square footages, rather than construct spaces amenable to either expanding or contracting in response to differing needs, limits the scope of actors able to occupy (and test) economic niches. Understanding how physical dynamics play a role in altering potentials within the economic landscape is, therefore, one of the contributions of this thesis.

D *Frame coming technological capacities*

The Internet of Things is positioned to be a game-changer in terms of how we consider the notion of infrastructure and flows. In much the same way that the rail-lines compressed space and time in terms of the flow of goods, the Internet compresses space and time in terms of the flow of information. Information is key in terms of coordinating and steering CAS dynamics, and never has it been so available to so many people. The implications of this new infrastructure are slowly becoming apparent, with a growing understanding that we can now coordinate activities and resources through the fluid interface of the web. The growing availability of big data will play a huge part in shaping our how our lives play out in the cities we inhabit, as people begin to share resources that involve the massive flow of ideas, goods, and resources. The scale and scope of these exchanges will need to be structured, and this structuring will not occur through top-down control but will be steered from the bottom-up.

While my initial goal was to focus only upon the morphological conditions through which CAS processes can be operationalized, over the course of time it became clear that some of the frictions within these processes occur at the points involving information transfer. By turning to hybrid systems that engage not only the morphological capacities of the city, but also the overlay of information channels provided by virtual interfaces, I have been able to fuse both virtual and physical systems such that they operate together in creating emergent conditions. The ideas contained in the latter part of the dissertation– ideas regarding signals, information and the feedback loops that result when productive regimes are in some way signified – can be used to help conceptualize and steer this new infrastructure.

Furthermore, the student projects described in Part Four of the dissertation are each examples of a CAS approach to design put to work. While they do go beyond the strictly morphological based nature of the initial work, they do so by incorporating digital capacities that simply enhance the information and signaling capacities of the morphological system. Beyond that, the methods they employ

follow directly from the key design points outlined in objective 'E' above. Within Part Three of the dissertation I ultimately came to see the urban fabric as an information processor, and so the fusing of information processing technologies within the fabric comes as a natural extension of this logic. It is my belief that many promising research directions will emerge from this convergence of the physical realm of the urban, together with the digital realm of virtual interfaces.

§ 10.5   Final Thoughts

In considering the breadth of these topics, I recognized that they may appear diffuse, and perhaps far too extensive to reside within the normal bounds of a Ph.D..

To put this into some context, I wish to note that this research has been unfolding over many years, during which time I have been engaged in both teaching and practice. I have, therefore, had ample opportunities to consider a broad range of urban issues through a complexity 'lens' that has in turn expanded my thinking outside the initial boundaries drawn in my Ph.D. research goals. I have been able to re-evaluate many assumptions about design, always with a CAS perspective in the back of my mind, and the breadth of the topics that I engage here reflects this ever-expanding view of how design issues might be re-imagined and re-engaged.

The work in this Ph.D. encompasses a wide array of issues. It provides a broad overview of the potential of a still nascent approach to design investigation and implementation. Much of the work is speculative, but this speculation is grounded in an analytical perspective that draws explicitly from the science of Complex Systems. While the thesis moves amongst many disparate topics, there is a unifying thread of inquiry that I have consistently worked to thicken throughout the course of this research. This pertains to understanding how the built fabric of cities is not merely a passive backdrop for human action, but rather an active enabler, instigator, and accommodator of urban flows and processes, *'a manifold of action possibilities'* (Withagen et al., 2012:251). It is my belief that these action possibilities - the full range of human activities and interests - can be more meaningfully and effectively channeled if we produce an urban fabric 'primed' to receive them. A fabric which can respond in a complex adaptive manner to better adapt its functional relationship to all of the variegated forces that act upon it, to operate in a way that is more tuned to an expanded phase space of potentials and individual needs. As a designer of urban environments, understanding how this might occur is both of personal relevance and, I believe, of significance to the design and planning professions.

On occasion, my pursuit of this understanding has taken me along various branches of thought, some of which have carried me far away from the key questions at stake. However, these 'lines of flight' have always led me back towards the centre – reinforcing my understanding of the key processes pertaining to CAS. It has been a truly engaging voyage of investigation and discovery, and I look forward to where it might carry me next.

- Sharon Wohl, 2018

CODA

Introduction to Part 6

The following article relates only loosely to the main body of this research. The article discusses a particular urban juncture – the Turkish Tea Garden – that occupies a central role in villages, towns, and cities in Turkey. The garden is a unique urban space, distinct not only in its morphological attributes, but also in the kinds of practices that occur as it is occupied. While the paper remains silent on the concept of Complex Adaptive Systems, the dissertation itself is not silent about the significance of such hubs.

In the article on the Grand Bazaar I indicate that complex systems are composed of particular nodes within the webs of urban interactions that act as particular points of concentration. Here, new ideas can be exchanged, or traditional protocols can be maintained and reinforced. Network theory in general speaks about the importance of such hubs, and of different kinds of hubs with different kinds of characters. In network analysis, a given hub (or node) might have a kind of global centrality – where it is a relay point between a large number of agents who do not interact directly with one another but may come to interact by virtue of their contact with one particular node. In other conditions, we have nodes in complex systems that act as 'bridges' where we have clusters of agents that are disassociated from one another, but where a particular node will act as a relay point between these two communities.

When we look to Evolutionary Economic Geography, there is also the notion that there need to be particular relay points for agent interactions. Different kinds of information are useful for different kinds of processes, but in general there is an idea that there needs to be a balance between 'local buzz' and 'global pipelines' (Bathelt et al., 2004a). Local buzz involves interaction that might pertain more to innovation, and what is happening in the moment on the street. Global pipelines refer to interaction that links a community with what is happening at broader scales, and the information about protocols or trends that might be larger in scope, but also slower in speed. In order to be nimble within a CAS landscape, agents are constantly navigating between accessing these two kinds of information domains, and hubs form the critical junctures that help steer this navigation.

In this dissertation, in order to provide a spatial analogy to this process, I partition the idea of hubs into two different kinds and scales – 'nodes' and 'landmarks' after Lynch - corresponding with the 'buzz' versus 'pipelines' analogy. In this conception, urban spaces that gather agent for more informal, casual interactions within tight communities would conform with the definition of 'buzz' or 'nodes', while urban spaces that gather agents from disparate regions, where knowledge transfer occurs not only within communities but across communities are considered as 'pipelines' or 'landmarks'. Looking at the Tea Garden as one such hub within the urban landscape is consistent with this perspective.

In the article that follows I indicate that tea gardens are unique kinds of spaces within the Turkish public realm, because they transcend neighbourhood divisions, with individuals from different parts laying equal claim upon this territory and all feeling a sense of shared belonging. Further, I argue that a different kind of tolerance occurs in these spaces then within other public realms – which goes beyond the localized exchange of those who are already similar (as occurs in neighbourhood coffee houses) to include an exchange between those that would normally be seen as 'other'. From a complexity perspective, such kinds of urban spaces need to exist in order for broader exchanges of information,

resources, and ideas to occur. Further, these kinds of spaces act as social stabilizers, keeping common traditions and practices of tolerance activated. Such anchoring junctures within the shifting landscape of CAS can also be seen as ensuring resilience – allowing some parts of the network to explore and recombine, while other parts maintain certain stabilities.

While most of the dissertation remains somewhat 'arms-length' insofar as examining any of the CAS processes at a detailed level, this article, while it does not mention CAS directly, nonetheless provides an in-depth exploration of how processes of agents coming together in a node occurs, and how this is supported by having certain tangible, physical, and morphological conditions of space present.

11 The Turkish Tea Garden: Exploring a 'Third Space' with Cultural Resonances

Abstract

This article examines the history, use, and significance of the Turkish Tea Garden or *Cay Bahcesi*, positing that these gardens offer unique democratic spaces for public discourse set within the polis. The article unpacks the historical, cultural and symbolic features of these gardens, and the role these shared spaces play in Turkey's multivalent civic environment. It employs Ray Oldenburg's notion of 'third space' to consider how these gardens provide inclusive settings for a culturally diverse citizenry. Further, the paper considers how these spaces act as repositories of shared memory, mediating conflict that appears in other societal spheres. The gardens are presented as uniquely 'sacred' third spaces, distinct from the 'profane' third spaces characterized by Oldenburg.

Note

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Introduction

Without the public oneiric spaces of the arcade or the square, without the people who can help us shape and articulate our wishes, we lack places to do our dreaming. We are left without sites on which to engage each other when we awake from that dreaming and try to make our wishes real. We are left without the most basic enabling conditions to create a world worthy of our aspirations. (Kingwell, 2001, page 190)

As citizens negotiating the space of the city, we share common terrain with those whom we see as '*other*': those manifesting difference be it through religion, ethnicity, culture, politics, or socio-economic standing. The city gathers together this variegated collection of individuals, many of whom have little in common, in spatial performances of politeness, propriety and publicity. In this pluralist world, cities cannot be conceived as homogenous entities in which citizens subscribe to a shared set of values and beliefs. Rather, cities must provide the cultural platform for a diverse citizenry, offering ways to *navigate* rather than *eliminate* political difference (Kingwell, 2001).

Settings that mediate these civic differences function as what urban sociologist Ray Oldenburg (1989) refers to as 'third spaces' – interstitial locales where citizens from all walks of life converge

in a casual setting for discourse. Oldenburg is interested in these particular places as settings where individuals engage in social contact with those from differing backgrounds. He cites pubs, barbershops and coffeehouses as examples of such spaces – environments distinct from the private realm of the home or the public realm of the workplace.[47] Yet all his examples point to environments that hold no particular cultural or spiritual significance for their users. Instead, they function as what Mercia Eliade (1987) refers to as 'profane' space, holding no deeper collective cultural resonance.

This article examines the history, use and role of a specific type of third space – the Tea Garden, or *Cay Bahcesi*. Using a combination of site observations, personal interviews, ethnographic research and academic sources, I trace the historical, cultural and symbolic features of these gardens, and the role these shared spaces play in Turkey's modern-day evolving, multivalent civic environment. I posit that these gardens, found throughout Turkey, provide a unique *sacred* third space within the structure of the polis, offering open, democratic, social spaces for public discourse within a setting that evokes deeply shared cultural meanings.

In the first section, I trace the historical and cultural backdrop that converges within the locus of the Tea Garden -- examining both coffeehouse traditions and a fusion of eastern garden traditions -- in order to explore the role these precedents play in generating common meaning and values in today's *Cay Bahcesi*. I then consider the need for Oldenburg's places of civility and common ground and how this need is particularly acute within Turkey's contemporary political and cultural context. Finally, I move on to examine present-day uses of the Tea Garden, considering their significance as sites that allow common cultural practices to be performed. I argue that the *Cay Bahcesi*, by providing the spatial context in which to situate these practices, offer unique value as shared cultural touchstones that help open gates of tolerance.

§ 11.1 Part 1: Historic Influences

A *The Coffeehouse Tradition*

The cultural practice of providing and enjoying refreshments within the Turkish public sphere can be traced back to civic amenities found within early Ottoman settlements. Historically, public fountains and kiosks (*sebils*), served as gathering nodes that distributed water, sweetened drinks, and juices to passers-by. These 'refreshment amenities', predate the establishment of coffeehouses, but suggest how infrastructure serving the need for refreshments held a privileged place within the public sphere (Hamadeh, 2008; Onay and Uğurlu, 2010). With the emergence of the coffeehouse tradition, this function took on deeper social and cultural dimensions.

Coffeehouses emerged from the Near East, arriving in Istanbul from Yemen in the mid 1500s. Initially, the beverage was consumed by members of the Sufi order, ostensibly to help them stay awake during their all-night devotional practices. Sufis drew their membership from a broad range of social and economic strata and were widely respected within the broader community. The consumption of coffee by Sufis, as part of their spiritual activities, imparted upon the beverage a sense of cultural legitimacy

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47   Lyn Lofland (1998) argues that many of Oldenburg's third spaces are in fact 'locations' (parochial) rather than 'locales' (public). Parochial spaces, while seemingly open to all are, in practice, sites of gathering for those who already share common belief systems – wherein these can become more firmly entrenched.

--helping prompt its widespread acceptance amongst the general public (Hattox, 2000). Coffeehouses came to be subsidized by the local wealthy elites, as part of their private contribution towards the public good. Their revenue streams contributed to the *Vakifs* (religious endowments), which supported the mosque and its works (Hamadeh, 2008; Ozkocak, 2007). Coffeehouses were therefore often located near mosques and were considered an integral part of the religious complex.

By the end of the 16th century Turks had embraced coffee and coffeehouses as an important new social institution, with this new gathering space exerted a sweeping effect upon the social practices of Istanbul's inhabitants. Acts of hospitality and sociability, by being granted cultural legitimacy through their association with the mosque complexes, could for the first time be respectfully transferred from the private domain of the home into the public domain of the city. For less wealthy citizens, who lacked homes large enough to receive visitors, coffeehouses could be used as a stand-in -- a space where one citizen could host another within the public realm (Mikhail, 2007). Coffeehouses thereby emerged as inclusive forums, frequented by people from a wide of array of social statures, including *'beys, nobles, officers, teachers, judges and other people of the law'* (d'Ohsson, 1788, cited in Hattox, 2000, p. 93). Here, citizens could enjoy sociability, entertainment, and the exchange of information (Hattox, 2000). Unlike stratified social environments, coffeehouses offered *'egalitarianism, congeniality and conversation'* (Ellis, 2008, page 157). While repeatedly the subject of government closures, the popularity of coffeehouses continued to spread and, being a major source of tax revenues, their status as an urban fixture eventually stabilized (Artan, 2011).

The Garden within the Coffeehouse context
....

Ralph Hattox (2000) identifies three types of coffeehouses: the take-out stall, the modest shop, and the grand 'house-style' coffeehouse that included an outdoor component. Hattox describes the coffee garden environment as offering, *'a park or gardenlike atmosphere … surround[ing] the patron with refreshing sights and sounds unlike those of either the city or the desert'* (2000, page 81). He also refers to the presence of outdoor mats, shade trees, trellises, and large benches. Descriptions of this outdoor aspect of coffeehouses are also found in various traveller diaries. In Julia Pardoe's accounts of Istanbul, for example, she describes *'a long street, terminating at the water's edge […] overshadowed by limes and acacias, beneath which are coffee terraces; constantly thronged with Turks, sitting gravely in groups upon low stools not more than half a foot from the ground'* (quoted by Hamadeh, 2008: 121, see also Johnson, 1922, p. 262). Coffeehouses are described as extending into the street (Tokman, 2001), where the coffeehouse opens *'onto a courtyard surrounded on three sides by wooden platforms with a pool and fountain in the center'* (Isin, 2003, page 88). Engraved plates depicting life in the 16th century provide further information about these outdoor spaces, with depictions that include those of kiosks along the Bosphorus, and cafés located near water features (Melling, 1807). Also identified are the games played at coffeehouses -- with backgammon, chess, and mankala being illustrated.

From these sources we understand that outdoor coffee gardens were an important compliment to the indoor coffeehouse experience. Nonetheless, while coffeehouses have been extensively studied, there is little documentation of their outdoor aspect. Consequently, our image of the coffeehouse is generally limited to that of either an interior space or, if outdoors, one that is somewhat analogous to a sidewalk café. Yet the coffee *garden* constituted a significant place for social gathering in its own right. These coffeehouse gardens provide a key spatial precedent for the Turkish Tea Garden, both in terms of their functional and physical components.

The shift from Coffee to Tea

Russian and Balkan immigrants who moved to Istanbul in the late 19th century brought with them the new custom of teahouses (and the gardens associated with them). These proved popular, in part due to tea being an inexpensive alternative to coffee (Tokman, 2001). In 1878 a Turkish governor wrote a pamphlet promoting the health benefits of tea, entitled the '*Çay Risalesi'*. This helped prompt the introduction of several teahouses in Istanbul and other cities (though coffee still dominated). But the full import of tea as a national drink emerged only after 1923. With the disintegration of the Ottoman Empire (and the loss of Yemen, Turkey's main source of coffee), Turkey was forced to import much more expensive coffee from Brazil. In 1924, in an effort to develop greater self–reliance, the government established a series of national tea plantations. Thereafter, tea became a much less expensive alternative to coffee. The ubiquity of tea drinking was further accelerated due to the fact that, in many areas, its consumption was considered to be safer than that of water (Ger and Kravets, 2009).

Following Ataturk's modernization program for Turkey, greater provision was made for the creation of public parks, with Tea Gardens becoming an important municipal feature within these environments. While each neighbourhood (*mahalle)* maintained parochial local coffeehouses, much more broadly attended municipal Tea Gardens were created at important civic sites, including those that had once been used as excursion grounds (Evyapan, 1999). These municipal sites, as opposed to 'belonging' to the more insular confines of the *mahalle,* attracted citizens from all parts of the city. The gardens became increasingly popular as socially inclusive environments, which '*brought men and women together at the same table'* in keeping with the desired '*European etiquette'* (Isin, 2003, p. 163). As part of the modernization project of Turkey, it was important that women have a visible place within public parks, thus removing the gender obstacles that remained intact within the neighbourhood coffeehouses. Further, with Istanbul's population growing rapidly, many families were moving into smaller homes that lacked gathering spaces to host friends. People therefore increasingly frequented Tea Gardens as spaces to meet. This combination of factors led to the increasing popularity of Tea Gardens in the 1950s as sites for families and friends to gather. The modern *Çay Bahcesi*, occupying a central position in the urban fabric, nonetheless enfolds practices that can be traced back to the 16th century coffee gardens (Ger & Kravets, 2009).

B   *Garden Traditions*

I wish to now consider the particular symbolic significance of *gardens* as the sites wherein tea is consumed. Garden traditions in Turkey draw upon a variety of influences: Islamic Paradisal garden traditions; Royal Pleasure gardens; and Turkic nomadic excursion grounds. While the social act of coffee drinking can be traced as the *functional and social* precedent of the Tea Garden, these various garden types provide the *physical and symbolic* precedents.

The idea of the Garden as Paradise, a sacred and visionary space, derives from early Islamic teachings. The word paradise comes from the Persian word *pairidaeza* referring to a walled enclosure (Moynihan, 1979). Islamic gardens were conceived as being a reflection of the heavenly paradise. Vivid descriptions of heaven depicted within the Koran gave guidance as to how these earthly gardens should be conceived with, '*greenery, gushing fountains, rivers, delicious food and sensual beauty'* (Schimmel, 1976, pages 17–18). Rulers would pride themselves on creating this man-made version of paradise -- conceived as a form of worship -- that linked the world of the mundane below to that of the sacred above. Wealthy Muslims, as a testament of their devotion, would endeavour to create this, '*paradise-like, cool and green garden'* that '*elevated the attitude towards nature, to the realm of religion'* (Evyapan, 1986, page 10).

These Islamic Paradisal gardens stood in opposition to their surrounding environments, constructed as walled oasis encompassing streams, trees and pavilions. The garden palette included water, trees, the division of earth into quarters, and the elevation of the mountain. Features such as the terracing of the garden were representative of varying levels of bliss (Moynihan, 1979). These paradisal gardens were intended to absorb peoples of different backgrounds and economic standing within their midst, providing a space of shared cultural practices experienced and performed through conversation, hospitality, love of nature and sociability. They not only served as locales for pleasure, leisure and the enjoyment of nature, but were also charged with symbolic content. The physical elements and spatial organization of the garden brought heavenly symbols to bear upon the secular activities of earth.

In contrast, Royal Pleasure gardens were a hedonistic space, conceived as outdoor spaces intended for the daily life and leisure of the court (MacDougall and Ettinghausen, 1974). The Sultan and his court would hold excursions to gardens in both urban locations and suburban estates (Brookshaw, 2003). Thirteenth Century documents describe Seljuk lands and villages, and include references to, '*pools and gardens and orchards and other trees […] and gathering places for residents and playing grounds for youth*' (Turan, quoted in Redford, 2000, p. 317). Construction of these gardens was inspired by an Islamic body of literature that made specific reference to the provision of public gardens as being associated with an ideal vision of governance, reflecting a just ruler (Redford, 2000). Thus, between the 11th and 13th centuries, Persian rulers would undertake the construction of gardens in order to convey both their power and sense of justice (Brookshaw, 2003). The royal pleasure grounds hosted scholarly as well as casual gatherings, wherein people enjoyed wine, food, dancing, poets, and musicians (Brookshaw, 2003). They were typically situated so as to take advantage of dramatic views, allowing the Sultan to survey his holdings, and included small structures and tent pavilions in which the Sultan could receive visitors. In the eighteenth century the royal pleasure gardens were made increasingly public as excursion grounds available to all social strata (Artan, 2011; Hamadeh, 2008). After the collapse of the Ottoman Empire it is these gardens that became public amenities, maintaining their role as excursion sites. As mentioned, the fact that these gardens were not considered the territory of any particular group made them much more inclusive settings compared to the local *mahalle* gathering sites.

A final factor colouring the nature of the Turkish garden is the nomadic character of the Turkic peoples. These roots led them to engage in a highly active use of gardens, placing within them functions that one would normally expect to be found within buildings. This practical uses of garden settings resonated with the nomadic use of the outdoors -- where nature is not so much brought under control, but adapted to serve everyday life (Seckin, 2003). Thus, while the Turks inherited key aspects of the Persian Garden tradition, they quickly adapted these for pragmatic requirements: altering the contemplative nature of the garden so that it could instead serve as an active setting for day-to-day life (Moynihan, 1979). While the geometry of traditional Persian gardens is formalized, with a specific organization of space intended to evoke paradise, the Turkish garden layout is conceived in a much more informal manner, in keeping with Nomadic traditions (Evyapan, 1986). In contrast to the inward looking Persian settings, Turkish gardens came to be outward looking, chosen for views, irrigation and weather conditions. They included naturalistic elements such as fountains, pools, pavilions and flowers. Gardens were also often situated at civic focal points near mosques and coffeehouses (Seckin, 2003). The Turkish garden therefore distinguishes itself from the Persian garden tradition insofar as it treats the natural environment as a semi-tamed venue for sociability, a place of social excursion rather than a rustic and wild setting for retreat or a sacred venue for contemplation. It is thus more informal, active, and naturalistic, while remaining rife with symbolic content (Evyapan, 1986).

Turkish Tea Gardens today

This specifically Turkish integration of the various garden traditions outlined above manifests itself in today's Tea Gardens. These are characterized by: informal layouts; water features; prime views; various options in terms of seating arrangements; and generous spacing between tables to allow for privacy. Local Tea Gardens are found within neighbourhoods, but civic Tea Gardens are either prominently located adjacent to municipal buildings or situated to take advantage of views or natural features. The boundary condition of the garden is clearly demarcated from the surrounding urban fabric, often with a low wall or elevation shift, creating a disjuncture with the everyday life of the city. In keeping with Turkish traditional use of outdoor space, people come to the Tea Gardens for unhurried relaxation, family events, conversation or games.

These gardens, I suggest, provide the third spaces Oldenburg regards as so important in establishing a meeting ground for disparate voices, but are unique insofar as they do so within *sacred* rather than profane space. This is in sharp contrast to the bars, bowling alleys and barbershops so often constituting the 'third spaces' normally cited.

§ 11.2 Part 2: Mediation and Civility in the Public Sphere

There is in fact no Kantian standard of universal rationality functioning beneath all our particularities, and so political stability cannot be secured by stripping those particularities away. Subordinating one's particularity to that false universal only means losing one's self, not preserving it. The political imperative, then, is not to secure individual rights under a larger political structure of generalized, and therefore empty respect, but to demand real respect for my particularity in the uniquely valuable project of living my life. (Kingwell, 2001, page 54)

I wish to now turn to the contemporary political and social significance of the Tea Garden, outlining some of the discussions bearing upon our understanding of social interactions in the public domain, and moving on to the specifics of how this applies to the Tea Garden. I argue that Tea Gardens sit outside of contemporary secularized Turkish space and in so doing tap into shared cultural memory.

Jurgen Habermas (1991) presents a detailed analysis of how citizens come together in the public realm, drawing our attention to the political importance of the public sphere. Making a distinction between interests that are private in nature and those affecting the *civitas*, he argues that the authority of a democratic government is insured, in part, by the fact that it represents viewpoints derived by an informed populace. Only in the context of the public sphere can individuals come together, leave their solely private pursuits behind, and arrive at consensus regarding the common good. In order for democracies to have a rational mandate for governance, there needs to be a sphere wherein such debate can occur. In the past, Habermas argues, coffeehouses and salons -- Oldenburg's third spaces -- played a vital role as the physical infrastructure wherein this debate could arise.

Habermas' views on the public sphere reflect a Universalist perspective, building upon Enlightenment ideals. He valorises the public sphere as being indispensable in a democracy -- but he ties this to a quest for a singular version of truth. In his thesis, there exists within the polis a dialectic encounter: wherein citizens with differing backgrounds and beliefs are able to meet within the public sphere for dialogue and gradually, through a rational encounter amongst informed speakers, come to a place of understanding and shared belief. Without this public sphere of encounter, people are confined to

their own parochial beliefs and perspectives, and knowledge is limited to what they already 'know' to be true.

Post-Modern thinkers are critical of Habermas' failure to adequately problematize how differences in perspective are not always resolvable through arrival at a common viewpoint (Kapoor, 2002; Mouffe, 1999). They also argue that he incorrectly assumes an equality of voices having access to public debate, whereas the public sphere is in fact a socially distorted environment – one wherein not all voices are equally expressed and heard -- and hence no universal truth can emerge. In addition, they find deeply problematic the perspective that valorises a quest for a singular legitimate truth 'out there', instead proposing a multiplicity of co-existing and contingent truths. Amongst his critics, philosopher Mark Kingwell questions his basis for a normative, universalizing objective for public debate, and similarly problematizes the productive capacity of reason. Kingwell argues:

This drive for a common language of political discussion is in some ways admirable, since it seeks to resolve disagreements rather than simply eliminate them, but at a fundamental level it is misconceived. Some ethical and political differences simply do not go away; some conflicts can never be resolved, only managed [...] We often have genuinely differences with those who share our political fate. We may dislike those we have to live with, or simply be indifferent to them. And yet these divergences will not surrender to reason, no matter how assiduous and extensive our attempts to resolve them in that way. (2001, pages 87, 89)

Kingwell's claims for the public sphere place a greater emphasis on generating tolerance amongst citizens, rather than transcendent truth. In his view, the aim of the public sphere is not to eliminate conflict, but rather to mediate it. Kingwell goes further, stating that differing viewpoints, and the inherent conflict associated with them, have a productive role to play in contributing to a just, democratic society – albeit as long as these differences are negotiated in a civil manner (see also Mouffe, 1999). It is rather the *suppression* of conflict that has destructive tendencies in limiting free expression.

Similarly, while there is growing concern about secular/Islamist rifts becoming more apparent in contemporary Turkish society, many argue that the *masking* of these rifts under the nationalist myth of a 'Modern' Turkey has been equally destructive. The Turkish Republic deliberately attempted to break with memories, symbols and religious beliefs of the past, in a revisionist 'official' version of 'Turkishness' that aimed to secularize society (Kucukcan, 2003). These reforms left gaping holes in the realms of tradition and cultural practices -- with shared ideals of Turkishness, in large part, an invention of a secular state struggling to manufacture a unified identity in the aftermath of Ottoman rule. This singular political unity of the country belied underlying disunities of culture, ethnicity and religion.

A growing body of work now challenges the so-called success of Turkey's modernization 'project' (Kasaba and Bozdogan, 1997), problematizing the Turkish Republic's homogenizing state narrative. Today, ethnic tensions suppressed through the unifying myth of a National Turkic identity have unravelled in the ongoing struggle with Kurdish peoples, who seek recognition of their distinct language and culture. Economic pressures have led to increasing rural to urban migrations, forcing seasoned urbanites to share spaces of encounter with those perceived as 'backward' newcomers (Robins and Aksoy, 1995). In this context, contested urbanities driven by religion or ethnicity, though present, have become less significant than cultural and economic distinctions. These rifts are increasingly bearing down upon a society struggling to mediate between ethnic, religious, socio-economic, and political tensions within the shared space of the polis.

These tensions have amplified as Turkey's political leadership increasingly realigns the country towards an Islamist identity. The AKP (Justice and Development Party) has embarked on a controversial cultural agenda to reassert Turkey's Ottoman heritage, long subsumed under the narrative of Ataturk's modernization and secularization project. But this reintroduction of Islamist symbols into the Turkish public sphere can be read in contested ways -- as indicative of a retrograde conservatism that threatens to suppress liberties associated with Republican modernization or, alternately, as a reclamation of specific cultural identities and distinctions, subsumed in an uncritical race to accept Western normative values (Çinar, 2005; Kasaba and Bozdogan, 1997).

Thus, depending upon the perspective taken, one can view the veiling of women in public space as either entailing freedom of personal expression *or* as a return to conservative religious restrictions; similarly, one can see the appearance of unveiled women in Kemalist public space as either a function of liberalization under Ataturk's reforms, *or* as evidence of the Kemalist appropriation of women's bodies as convenient tools for Statist propaganda, serving an elitist political agenda (Arat, 1997). Each reading is possible, and perspectives shift in accordance with individual situations. Thus, while secularists worry about the gradual normalization of the headscarf, members of the gay/lesbian communities join in protesting the ban of the headscarf at universities in a show of solidarity for freedom of expression. Similarly, a population of Islamists and secularists, Kurds, and LGBTTQ activists came together in the Gezi Park protests, rallying against a government seen by all as becoming increasingly authoritarian (Ors, 2014). Secular Turks at times support an Islamist government in order to ensure economic stability, whilst simultaneously rejecting Islamist ideology. While the Islamist tendencies of the AKP have generated controversy, that has not stopped both Liberals and Islamists from launching criticisms towards the earlier Kemalist project, increasingly seen by all as being paternalistic and authoritarian, negating, '*the historical and cultural experience of the people of Turkey*' (Kasaba & Bozdogan, 1997, p. 4). In Turkey today, neat divisions of identities fail to remain fixed and static, and simple binaries -- conservative/modern, Kurdish/Turkish, secular/fundamentalist -- unravel in the face of complexities manifested in lived experience (Turam, 2012, 2013).

Turkish public space holds together this array of shifting identities, often at odds but also mediated within specific contexts of unified vision. Many average Turks lament what they see as a political desire to cause rifts amongst the populace, where seemingly polarizing issues concerning 'veiled versus unveiled' or 'secular versus Islamist', are amplified by political activists, but are not perceived as resonating with lived experience (see also Heper, 2011, who analyses opinion polls confirming this perspective). Thus, '*the plurality one finds on streets still defy the simplified ideological polarization that pits secularists and Islamists against each other with seemingly clear faultlines*' (Gökarıksel, 2011, page 12). Increasingly, global economic dynamics are bringing a diverse citizenry together in urban space, rubbing shoulder to shoulder as previously isolated groups begin to inhabit the same milieu: dissolving boundaries that once held difference apart. This creates new tensions as the public sphere becomes a much more complex space to navigate, at risk of fracturing into insular segments, held separate by demarcation lines made physical or perceptual (Davis, 1992). And yet rather than being oppositional, day-to-day experience in Turkey is often mediated by more nuanced 'in-between' spaces of encounter, ones offering possibilities for shifting identities.

Oldenburg's third spaces are the locales wherein the Habermasian play of civility and dialogue occur, but in the Turkish instance, it becomes clear that finding a 'universal' set of values within the public realm is no longer possible (nor desirable). Further, '*affinities, shared goals and political alliances also originate from **contested** urban space, where interaction, albeit propelled by uncomfortable proximities, is preferable to segregation*' (Turam, 2013, p. 426, emphasis added). I believe Tea Gardens offer one such contested space: a space occupied by many where the enactment of shared

practices establishes common ground and where conflicts, at least temporarily, can be suspended. Rather than seeing the Tea Garden as somewhere along yet another conceptual binary -- one that juxtaposes 'liberal/modern' alcohol serving establishments against 'backward/conservative' *Cay Bahcesi* -- Tea Gardens occupy a much more nuanced social hybrid, one that taps into shared memory and mythos.

§ 11.3   **Part 3: Conclusion - Tea Gardens as Shared Cultural Touchstones?**

Human memory is spatial. The shaping of space is an instrument for the shaping of memory. A shared space – such as a street – can be a locus of collective memory…it can express the accumulation of memories from below, through the physical and associative traces left by interweaving patterns of everyday life. (Hebbert, 2005, page 592)

Geographer Amy Mills, in her study of cultural co-existence in Istanbul, highlights the specific role that *memory* serves as a vehicle for constructing shared beliefs and identities (2010). Mills identifies how physical space can provide the infrastructure that memory cleaves to, *'the social space through and on which memory is constructed'* where we *'imagine, narrate and practice the social relationships that make us who we are'* (Mills, 2010, page 205). Yet many everyday spaces of life are without history, without memory. This was, in fact, a core part of the Kemalist agenda, best exemplified in the selection of Ankara -- a town with no historical 'baggage' per say -- as the state's new capital (Sargin, 2004). The Kemalist program, with its aim to break from the Ottoman past, led Turks to associate a sense of shame and embarrassment with anything tied to a heritage seen as decadent and backwards (Çinar, 2008).

But this break with memory left Turks in an uneasy relationship both in regards to their conceptions of a shared past and their ambitions for a shared future. A disconnect between a desired and imagined Western superiority versus the actuality of lived experience continues to be enacted today. Westernized consumer spaces have colonized the Turkish public domain with an endless barrage of international corporate brands and logos, and with spatial environments that could exist equally in Ankara or London. Meaning, if any, associated with these malls and chains has been manufactured by marketers. At the same time, these spaces are viscerally biased toward a sense of western superiority -- the notion that 'modern' values associated with consumption in the West are somehow an improvement over the 'backwardness' of the Eastern Bazaar. Seen within this context, the popularity of Tea Gardens can be viewed either as evidence of culturally conservative nostalgia (arabesque) or as an empowering reclamation of a heritage censured through the glorification of Western values.

Much of the struggle being enacted in Turkish society today involves this quest to reclaim authenticity: to seek roots tied to specificities of culture and place. Two young scholars from Turkey provided me with one anecdotal example of how this search for shared meanings is performed. They related how in the 1990s a series of western-style café's opened in Istanbul. Initially, many young people wanted to go to experience that culture, but over time the seduction of these environments waned (see also Tokman, 2001, who discusses the same phenomena). Instead there was a desire to return to one's *own roots* at the Tea Gardens, where people felt a*t home* rather than on show. The unique sense of place experienced in these gardens had to do with a feeling that these environments were uniquely Turkish, embodying shared values. What was expressed to me was that in the gardens the posture one took felt *natural* and unaffected. This was in contrast with the Westernized cafés, where the pressures

of everyday life and appearances continued to bear down upon patrons, even as they took their coffee breaks. This distinction between gardens and cafés was a recurrent theme in my interviews, where subjects reported a different relationship with time in these settings (see also Ger & Kravets, 2009). In the gardens, one could 'spend hours' without pressure and 'tea is offered' rather than sold. Cafés, in contrast, were seen as spaces of consumption where ordinary (and secular) time continued to prevail.

The use of the Tea Garden is ubiquitous across Turkey, transcending other differences and in many instances otherwise segregated groups come together in these venues. One interviewee noted that *'Turkish people will fight anywhere, but not in Tea Gardens'*. Echoing this sentiment, anthropologist Christopher Houston observes how conflicts and suspicions are temporarily suspended within the Tea Garden, allowing new relations amongst people to be imagined. The space performs, *'as neutral ground by both Islamist and laic subjects ...[where] the 'dark' and 'civilized' faces of Islam sip tea, drop crumbs and fill ashtrays side by side, sometimes even at the same table'* (2001, page 86). Similarly, a newspaper columnist describing the array of identities co-mingling in a Tea Garden in Bursa, writes, *'most of the young women wear the loose-fitting headscarves traditional in Turkey; others, the more elaborate and constraining ones that are a mark of newer currents in political Islam. Still others are on the dance floor, uncovered, bare-armed, dancing in an implausibly immodest way'* (Caldwell, 2005).

Here diverse identities occupy the same public sphere -- tolerating difference in a nod to possible co-existence (Secor, 2004). The performance of shared social practices involving leisure, conversation, games, and tea-drinking point to a common heritage and fate, while their re-constitution makes it possible to imagine a peaceful co-existence in the future. The power of these unifying social practices forms bridges of understanding between those who are otherwise at odds. Thus, if 'my' belief and practice echoes 'your' belief and practice, if we are able to honour the same rituals and rites of everyday life, then it becomes increasingly difficult to identify you as 'other'. The customs and cultural practices of the Tea Garden hold symbolic meaning for *all* who engage this space, whether perceived through the lens of religious doctrine, or from a secularist standpoint. The performance of these practices are, in turn, a re-enactment of mythic ideals from the past -- pointing to open, respectful cosmopolitanism.

I am well aware that this nostalgic yearning for a multi-cultural inclusive past is complex and that the trope of cosmopolitan tolerance is not innocent. It masks inconvenient truths that fail to congeal with the narrative of tolerance (Hanley, 2008). Furthermore, while seemingly appearing as 'inclusive' there is also a sense that the concept of 'cosmopolitanism' is linked to a European sensibility towards inclusion -- valorizing a sort of liberal and Western 'person of the world' versus granting cosmopolitan status to 'multiple distinct persons in the world'. This need for a truly inclusive public sphere that includes *all* practices of Turks is particularly acute today. But the ubiquity of *'Ottoman mulit-ethnic tolerance'* as a common cultural trope, cited by *'leftists, human rights activists, secularists, and intellectuals, as well as Islamist politicians and conservatives'* (Mills, 2011, page 193), nonetheless points to a common *desire* for an acceptance of plurality -- a resistance to the hegemonic imposition of a singular Nationalist rhetoric.

In many locales within the city, it is difficult to preserve, empower, and reproduce this mythic memory of tolerance. The division of cities like Istanbul into specific insular neighbourhoods keeps individuals apart, establishes distinct territories, and propagates notions of perceived difference. But Turkey, and Istanbul in particular, is a complex and uneven terrain holding both spaces of segregation and areas of rapprochement (Secor, 2004). Due to their spatial lineage as special territories situated in unique settings of the city, Tea Gardens cannot be claimed by any one specific group. They are not defined by a particular neighbourhood or *mahalle* but are instead bridging nodes that 'belong' to the citizenry as a whole. They thereby exist perceptually as a special case within the urban fabric, as apart from the

city now as they were in the past when walled off as heavenly enclosures. This sacred space allows for a conceptual disjuncture with the surrounding 'profane' city and its tensions, and for special types of behaviours to unfold within their demarcation lines.

The Tea Garden reconstitutes and concretizes memories surrounding a place where it is possible to interact peacefully with one another.[48] It holds commonly shared visceral associations with both sacred notions of the Earthly Paradise and Coffeehouse virtues of openness, respect, and civility -- associations that pre-date many contemporary sources of conflict. These associations weave together shared history, culture practices, and sacred symbolism, to confer an *elevated* meaning upon the act of social gathering (in contrast to Oldenburg's profane third spaces). Within the *Cay Bahcesi* memories are re-enacted within a spatial setting that exists as part of an unbroken tradition, a *milieux de memoire* where memory remains embodied as social practice, taking root '*in the concrete, in spaces, gestures, images and objects*' (Nora, 1989, page 9). The gardens act as a specific locality where memory and narrative are gathered in a space with shared cultural allusions to the sacred. The gardens serve as repositories of shared customs, collective beliefs, and historic memories -- including those real, imagined, and mythic in substance.

In order to build a truly inclusive Turkish Society, one able to accommodate difference rather than merely suppress it under state ideology, there need to be spaces that allow different factions of society to come together and begin to envisage common dreams under a socially agreed upon narrative of peaceful co-existence. Opening the notion of cosmopolitanism up beyond its Western connotations to allow for multiple identities, is key to creating 'in-between' places that allow for mediated, multiple and divergent identities (Ors, 2002). Peace and tolerance may need to begin with imagination, with constructing narratives and memory: tolerance may at times be temporary and contingent; more mythic than real; and co-existence may be more about pointing towards a desired future then providing an accurate representation of present or past. But this does not diminish the productive capacity of this shared mythos to weave peoples together, regardless of whether or not it masks historical inaccuracies, or glosses over present-day contradictions. In order to build a society for the future, spaces of memory that point to a respectful relationship in the past can act as powerful cultural touchstones to generate unifying ties amongst disparate peoples. Here, the *Cay Bahcesi* offers a unique, sacred, third space to concretize the dreams and aspirations of peaceful co-existence.

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48   For a discussion on how memory is captured in space see (Halbwachs and Coser, 1992)

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2005 - 2008	Contract Professor, Environmental Design Program, University of Manitoba, Wpg, MB
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Publications

— Wohl (as Ackerman), S. (2010). Book Reviews: Integral City and City out of Chaos. Canadian Journal of Urban Research, 43(4), 129–133.

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2018
— *"Tailored turfs, optimized orders, or insular enclaves - Projecting the possibilities of civic data"*
ACSA Meeting 'The Next Digital Turn': Identifying Inequalities Track; Denver, Colorado

2017
— *"Boosting Innovative Capacities - Cultivating affordances within self-organizing cities"*
New Sciences and Actions for Complex Cities; Florence, Italy
— *"Sensing the City – Legibility in the context of mediated spatial terrains"*
Space and Culture: 'The Idea of Place'; Edmonton, Canada
— *"Deploying CAS dynamics within the Urban Fabric: thought experiments"*
AESOP Planning and Complexity 15th meeting
Crossing over with Complexity: Co-evolution in Planning; Ghent, Belgium

2016
— *"Research in Urbanism and Planning Stemming from CAS Theory: An Overview"*
AESOP Planning and Complexity 14th Meeting:
Taking Stock of Complexity Sciences; Bamberg, Germany
— *"The Smartphone as Urban Mediator and 'Sixth-Sense"* (with Sean Wittmeyer)
AESOP Planning and Complexity 14th Meeting:
Taking Stock of Complexity Sciences; Bamberg, Germany

2015
— *"Employing CAS Theory and New Digital Platforms to Promote Emergent Participatory Growth"*
8th CITTA Conference (with Jeff Givens)
AESOP Thematic Group on Public Spaces & Urban Cultures; Porto, Portugal

2014
— *"Considering how morphological traits of urban fabric create affordance for Complex Adaption"*
AESOP General Meeting - From Control to Co-Evolution,
Track 14: Evolutionary Urban Economy; Utrecht, the Netherlands
— *"From Form to Process: Reconsidering Lynch in light of Complexity Theory"*
AESOP General Meeting - From Control to Co-Evolution,
Track 4: Complexity and Planning Theory; Utrecht, the Netherlands
— *"Situating Complexity in Contemporary Landscape Urbanism Strategies"*
AESOP Planning and Complexity 12th Meeting:
Confronting Urban Design & Complexity; Manchester, England

2013
— *"Applying Principle from Complex Adaptive Systems Theory towards Urban Planning Strategies"*
AESOP Planning and Complexity 11th Meeting:
Self-organization and Spatial Planning; Aveiro, Portugal
— *"Anchoring the Fluid Workspace: An Exploration on the Role of Spatial Archetypes"*
Spaces and Flows Conference; Amsterdam, The Netherlands (with Jennifer Jenkins)

2012

— *"Complexity in Self-Organizing Urban Structure – Material Carriers of Complex Systems in Urban Processes"*
European Conference on Complex Systems; Brussels, Belgium

2011

— *"Conceptualizing Distributed Workspaces as Complex Adaptive Systems" (with Jennifer Jenkins)*
NECSI International Conference on Complex Systems; Boston, USA
— *"Turkish Tea Gardens: A Third Space Public Space"*
International Praxis Conference on Culture, Memory and Coexistence; Istanbul, Turkey

2007

— *"Aesthetics of Sensoral Fusion" (with Tijen Roshko)*
17th International Congress of Aesthetics; Ankara, Turkey

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— *"Emergence and Urban Design Theory"*
Complexity, Science and Society Conference; Liverpool, England

Professional Experience

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1995 - 2000	Planner/Junior Architect, Cohlmeyer Architect; Winnipeg, MB
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