

Planning Local and Regional Development:
Exploring Network Signals, Sites, and Economic Opportunity Dynamics

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ABSTRACT

Urban development planning efforts are challenged to enhance coevolving spatial and socioeconomic systems that exist and interact at multiple scales. While network and simulation sciences have created new tools and theories suitable for urban studies, models of development are not yet suitable for local and regional development planning. A case study of the City of Roanoke, Virginia, grounded network development theories of scaling, engagement, and collective perception function, as well as network forms. By advancing urban development network theory, frameworks for urban simulation like agent-based models take more coherent shape. This in turn better positions decision-making and planning practitioners to adapt, transform, or renew local network-oriented development systems, and conceptualize a framework for computational urban development planning for regions and localities.

Acknowledgements

Studying processes of development, adaptation, and community for a dissertation will provide many moments to appreciate the resources and support others provide, and moments of humbling recognition when you discover how much you still have to learn. Development takes years. Adaptation is usually hard. Communities change constantly.

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Preface & Attributes

The research project detailed here was the principal responsibility of the author under the supervision of dissertation committee members. Each worked to provide topical and methodological guidance and critique. As an interdisciplinary effort the author endeavored to bring their separate expertise into direct relationship, hence very little of this project would have been possible without their willing collaboration and willingness to extend beyond disciplinary comfort zones.

All committee members provided theoretical, methodological, and source guidance. John Randolph shepherded the project and committee as the project evolved, in addition to providing critiques on all chapter drafts. Shalini Misra provided research oversight of the interviews in Chapter 4, and provided research design and conceptual critiques and line edits for other chapters as well. Madhav Marathe made conceptual suggestions implemented into the models and discussions in Chapters 5 and 6, and pushed for greater development of formal network definitions in Chapters 3 & 4. John Provo provided conceptual critiques and methodological development throughout the project and chapters.

Chapter 1: Introduction

Developing urban regions and localities raise significant challenges. There are programs to upgrade the infrastructure of sites, programs to upgrade the skills of populations, and programs to invest in the development of new knowledge, products, and services. There are very few programs that manage to invest on multiple levels to coordinate policies. Indeed, many cities and regions show evidence of contradictory development trends. Intergenerational poverty trends vie with gentrification patterns, and deindustrialization trends mix with new investments in automated manufacturing technologies. Few regions have functional equity or strategic planning policies to begin to adjust quickly to any development challenge—obsolescence, opportunity, deprivation, or congestion. Investments are made without a plan for managing costs and benefits relative to specific local populations in neighborhoods. It is difficult to know what the jobs of the future will be, and hence where they will be located. Despite this, the social construction of economic opportunities and skill capabilities are central to understanding economic development (Feldman 2014). For urban communities, economic behaviors and organization are constructed collectively through spatial networks and place-based social affiliation dynamics like neighborhoods, institutions, and investment relationships. So how can the construction of urban opportunities and economic capabilities be better understood in community contexts well enough to plan them?

Approaching these issues in this way, through a Structuralist philosophical lens, seeks to better understand or theorize how interaction patterns stem from distribution, organization, and connection features of urban systems. These are also important topics for network science. Where communities and economies are failing, perhaps systemic network interventions can support stronger planning approaches. Urban systems and interdisciplinary network structures are difficult to define without better integrating theories, however. There is a growing literature that argues that urban areas are nonlinear *complex adaptive systems* (Batty and Marshall 2012). In order to research the mutually dependent, or *co-evolving* generation of development outcomes, network approaches that can graph and/or simulate these complex mutual interactions have become extremely important.

Just as Kevin Lynch's (1960) *Image of the City* explored how people orient themselves in physical urban spaces, research is needed to better expose how people utilize economic networks for development decisions. Economic information and incentives can be filtered through a local economy's social, transport, and other commercial networks. In order to better orient or align business sector trajectories, regional capital deployment, and individual business decisions, what do people need from their cities and neighborhoods? What is the role that access to key economic locations and associated networks (or perhaps key networks and associated sites) plays in improving processes of coordinating and sharing important economic planning information at different locations and levels of scale?

As physical beings, individuals and groups often connect with different networks at specific physical locations and environments. But not every community in a region has the same access to information and resources. Indeed, many communities have distinct economic identities (Esri 2013). These discrete community typologies also contain and facilitate, or structure, access to specific economic information processing sites like co-working spaces, vocational schools, research institutions, and local chambers of commerce. The information processing functions of such sites—generated by local networks operating at the interfaces of social, physical, and financial systems—combine to provide the actual functional infrastructure of development (Bourdieu et al. 2012).

Getting the planning and coordination right for key development goals and outcomes—like skilled labor supplies and entrepreneurial activities—has recently included strategies and targeted investments in education and training, cultural amenities, and technical infrastructure to enable and incentivize desired behaviors. Understanding how the network dynamics and architecture of the information processing and signal elements function to coordinate or inhibit individual economic behaviors at certain sites in urban environments, may provide new powerful planning tools for contemporary U.S. local and regional developers, leaders, and activists. So how can we better understand the network dynamics of economic development at the local to regional levels?

The exchanges and processing of signals, including informational, financial, and environmental resource flows are fundamental to the social and physical generation and regeneration of economic opportunities and capacities. *The purpose of this research is to*

*contribute to the **grounding of development theory** to better understand the **network characteristics** of economic opportunities and capabilities in a community and regional context.*

Contemporary development research has made progress in studying urban spatial, economic, and social data, and research can now be applied towards theorizing structures between these networks. *A key topic of study includes how such spatial, social, and commercial networks—and the networks between these different types of networks—are **constructed**. Network methods and theories can contribute to understanding how to support the formation of certain links and nodes in urban sites. Furthermore, this research proposes to conceptualize strategies to use different **simulation and network science tools and methodologies** to enhance future research and applied development planning efforts.*

Because opportunities and capabilities stem from mutually co-evolving informational, personal, and locational dynamics, a mixed methods research approach is suggested to better ground and test extent network theory for suitability in development planning. In his book about network research approaches for cities, Zachary Neal (2013) defined networks as “specific and observable patterns of relationships that can be directly or indirectly examined.” He stresses that when studying networks, it is important to focus on literal, observable (empirical) networks rather than the merely metaphorical or vague sense of the term. He states that a network approach to cities is **both a methodology and theoretical perspective** since networks are not just about data analytics of links and nodes, but also a way of thinking about the world (p. 3). In thinking about observable relationship patterns related to development patterns, the research design challenges are many.

In an era of globalization and knowledge economies, there is not a simple answer to what constitutes economic development activity. There are no simple answers as to how individuals orient themselves towards and within social and physical environments of exchanges in information and resources. There are no simple answers as to how planning interventions could be empirically (or normatively) designed to guide the weighing of potential social or environmental network changes and strategies. There are,

however, a great many theoretical puzzle pieces that shrink the overall parameters of inquiry in order to get a clearer research picture.

Many cities and regions have distinct urban morphologies and social norms which can make network study more or less difficult. Understanding the network character—the why, where, when, how, and scale—of economic opportunity access in contemporary urban locations is essential to appropriate planning of complex systems where initial conditions and interactions are hugely important for managing change. In order to explore observable urban patterns at multiple sites, a case study of a small city was ideal. Large metropolitan areas have scale advantages and more extensive global network dynamics than smaller regions. This can make coevolving network interactions harder to observe across the whole urban system, and a complex adaptive system must be systematically graphed. A relatively isolated urban area, the City of Roanoke, Virginia has a population just below a hundred thousand people with multiple commercial neighborhood sites at various levels of prosperity. Some of its sites were well-suited for observation, analysis, and interview research to understand how residents perceive urban networks and development, so the selected network methodologies could be applied there. Roanoke was selected as the study region.

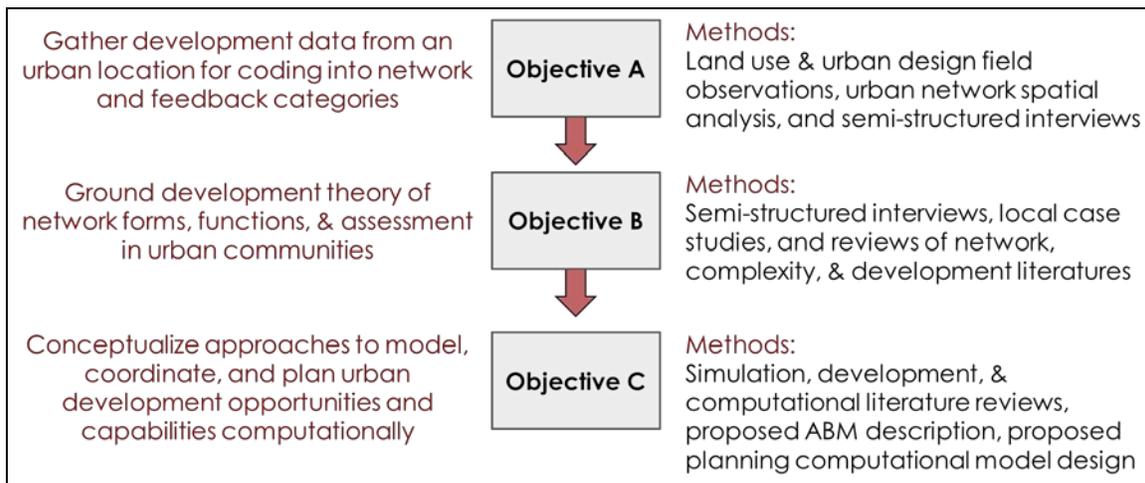
However, one major problem with a network approach is that very few if any localities conceive of themselves as development nodes, edges, and flows. Typically, an urban system, region, or economy is made of active agents and organizations which do not see themselves as a connected, mutually co-evolving complex adaptive system either. In order to understand how opportunities and capabilities are constructed in community contexts, the following research questions are addressed in turn:

- a) *Which spatial components characterize Roanoke development **network** activity, and*
- b) *What development information **dynamics** occur at specific Roanoke sites?*
- c) *How can complex urban development patterns be **simulated**?*

- d) *How can urban development planning be defined computationally, and how might urban development planning systems be computationally enhanced toward **adaptive** functions at multiple spatial levels?*

As these questions guide research to build towards better answers and subsequent questions, the three research objectives (Figure 1) include gathering development data from an urban location for coding into network data categories, grounding a development theory for network categories, and conceptualizing network synchronization models and planning systems suitable for complex adaptive systems to better support development planning.

Figure 1: Research objectives and methods



A mixed methods study best explores these research topics. Chapter 2 is a literature review to identify several lines of research in development to clarify some of the ways that spatial, social, economic, and complexity dynamics have been explored to date though much literature is reviewed in subsequent chapters. Chapters 3 and 4 begin to ground theory for the interpretation and measurement of network effects related to local economic development through a network dynamics case study of the City of Roanoke, Virginia. In this study, transportation networks, zoning maps, and field interview data will be used to assess the development history and potential of Roanoke commercial neighborhood sites. Visual analysis and surveys of users of economically important sites

and institutions will explore their functional qualities for Roanoke residents in order to understand them as networks.

The research methodology includes several different forms of inquiry to understand the network dynamics of development at the local level in terms of specific public interaction sites, entrepreneurial and other skill development activity networks (and associated sites), and indicators relating both to local and larger scale economic outcomes. This means that various forms of qualitative and quantitative assessment will be applied to further clarify theoretical links and gaps associated with a network approach to local development, and then those findings will be benchmarked to certain quantitative economic indicators. The difficulty of datasets appropriate for this case study is a serious challenge for researching the mutually evolving locational and personal dynamics. Of major concern is also the means by which both case studies and data can be rendered in formats useful for systematic network characterization and comparison as called for by a grounded theoretical approach. Because the network effects of interest are social ties, place ties, information dynamics, and financial states, data gathering occurred at both certain specific sites as well as for the urban system, generally.

By framing the specific local environments with important economic behaviors and information flows that serve to create local development opportunities, the goal is to better understand the ways these network types and behaviors are compared between and within different commercial neighborhoods. This may serve to close the gap in understanding between input behaviors by individuals in specific areas and output levels of employment, business enterprise creation, and wage improvements as network effects.

Categorization of this signal and social network environment at street and building level assists subsequent research studies such as mapping, quantitative and qualitative analysis and significance testing, and complex simulation experiments. This study is focused on the neighborhood impacts of specific public forms, information functions, and accessibility of economic collaborative zones for communities generally, as accessed by individuals. This supports a better understanding of where development collaborations actually take place in commercial neighborhood environments outside corporate or residential dominated sites within a region. Chapter 5 explores how a tool

for studying complexity called agent-based modeling can be used for extending these development inquiries.

The reason for this mixed methodology is to ground network economic development theory description from the overlapping conceptual contributions of a number of interdisciplinary fields. Additionally, more applied network methods need more validation so that economic development planning might be better positioned to design enhancements like better opportunity access and capacities to enhance wages, employment, and physical infrastructure investment within a local economy. A conceptual discussion of such a *network-oriented* urban development planning approach is the subject of Chapter 6.

Because of complex relationships, it is not possible to focus exclusively on one aspect of network effects. Instead, the focus of the research proposed here is to describe *co-evolving* network development factors and dynamics to frame the essential network functions and behaviors associated with improving success rates over time involving specific network interactions within particular physical environments. This equates to local social networks' ability to establish and nurture successful business planning and coordination, worker training and participation dynamics, and ongoing positive flows and distribution of investment resources. Economic development planning remains extremely challenging, and a clearer understanding of these complex network relationships is essential. This mixed methods research seeks to advance that effort.

References

- Batty, M., & Marshall, S. (2012). The Origins of Complexity Theory in Cities and Planning. In J. Portugali, Meyer, H., Stolk, E., and Tan, E. (eds.) *Complexity Theories of Cities Have Come of Age: An overview with implications to urban planning and design*. New York: Springer: 24-47.
- Bourdic, L., Salat, S., & Nowacki, C. (2012). Assessing cities: A new system of cross-scale spatial indicators. *Building Research and Information*, 40(5), 592-605.
- Esri (2013, March). Methodology Statement: Esri Data—Tapestry Segmentation. *Esri White Paper*. Retrieved from: <http://www.esri.com/library/whitepapers/pdfs/esri-data-tapestry-segmentation.pdf>.
- Feldman, M. P. (2014). The character of innovative places: Entrepreneurial strategy, economic development, and prosperity. *Small Business Economics*, 43(1), 9-20.
- Lynch, K. (1960). *The image of the city*. Cambridge [Mass.]: Technology Press.
- Neal, Z. P. (2013). *The connected city: How networks are shaping the modern metropolis*. GB: Routledge Ltd. doi:104324/9780203101728.

Chapter 2: Urban Development Planning, Adaptation, and Modeling A Complexity Literature Review

Improving urban development, inclusive of economic and community development, is a critical challenge for a rapidly urbanizing world. Increasingly, questions as to how localities can plan for and achieve reliable prosperity in a connected, competitive global system have become more urgent and generated divergent strategies and models. The standard or neoclassical economic models are based on “rational actors” whose behaviors within the model are assumed, optimized, and uniform. However, in order to model local dynamics, the capacity to model heterogeneous actor or “agent” behaviors more reflective of actual behaviors identified in case studies, ethnographies, and other research has opened up tremendous opportunities to study development with far more specificity, flexibility, and creativity. The application of discoveries in *complex adaptive systems* (CAS) related to patterns found in many physical, biological, and social systems, is also expanding research in urban development. Complex systems are those which are neither ordered enough to provide linear relationships nor so random that they cannot be modeled at all. Their larger patterns are created via interactive effects like feedback that incorporate mutual influences between individual agents and their larger context such as a network or ecosystem (see Alberti 2008). For development purposes, this means that individuals are both affected by and in turn affect their communities through information flows, which means that methods like computational modeling that explore or mimic these flows and associated transformations have enormous potential for understanding and experimenting with emerging challenges.

Research into CAS applications and insights has increased dramatically over the last two decades. It is the purpose of this chapter to explore only a narrow segment of this literature, for the most part focused on complex systems models relating to economic and community development. Additionally, a number of select models and research trajectories related to key concepts from outside development studies (but well within CAS studies) suggest areas of future simulation research with development applications.

Specifically, studies in the science of cities, evolutionary economics, development agent-based models, case studies, and finally networks, diversity, and informatics are reviewed below. As part of the case studies portion, a number of important (but not

overtly CAS) development studies are also addressed to better situate the areas of overlap and divergence with the larger economic, planning, and sociology fields. More thorough treatments of planning, development, and complex adaptive systems are available elsewhere (see also Batty 2005; Portugali 2011), but the focus here is on models suitable for adaptive economic and community development.

The unique applicability of CAS and certain kinds of agent simulation modeling to development studies is first introduced, followed by the key framework and associated questions, and then finally the literature is discussed to frame the larger complexity, development, and simulation research agenda. Because of the interdisciplinary scope of these topics, the vast bulk of the literature is reviewed topically in each subsequent chapter. It is important to note that both sources reviewed here and later form part of larger research efforts with implications not just for urban development but for the whole of planning and governance.

Complexity and adaptation

Despite a growing multidisciplinary literature, there are still no standard and consistent definitions available for complex systems. Martin and Sunley (2007, p. 577) condense seven “generic properties” characteristic of the most important complex systems themes. The biggest utility of complex system approaches for development are precisely these distributed, open, adaptive, interactive, non-reducible, self-organizing, and unpredictable features which are so important for community and economic dynamics. While acknowledging the lack of a universal theory, they concur with others that complex systems are distinctive in their *coevolutionary* interactions, emergent self-organizing behavior, and adaptive capacity to rearrange their internal structure.

However, a major difference between CAS studies and the bulk of development research over the last several decades is the distinction between reductionist and correlation statistical methodologies that seek to isolate and control for research variables. The reason for applying complexity approaches to development problems is that micro-motives often do not equal macro-behaviors in human societies (Schelling 1978). For spatial pattern models, cause and effect studies are better understood or “grown” as Epstein & Axtell (1996) describe it with agent-based modeling (ABM) or

other complex modeling capable of reflecting many different behaviors of individuals interacting with each other through feedback and feed-forward patterns that dynamically alter results as computer simulations unfold geometrically (see Railsback & Grimm 2012). As hardware, software, and methodologies have improved, complex modeling is exploring such interactive dynamics with increasing power and originality with often fascinating results (Epstein 2006).

Even with these expanded capabilities, capturing important answers to development questions remains very challenging. Key questions at the center of development research include: what or who is to be developed, how that is to be defined, and what models can tell us about the interactions and appropriate scales of interventions. Model thinking helps us to understand that individuals, businesses, communities, governments, and other groups and institutions can possibly be modeled in their own right or form components of other larger scale actors all of which can be developed or mutually interact in some way and at various scales. This is the *complex* part of these problems. How do we define development? It can be defined as adding capacity, efficiency, resiliency, sustainability, resources, or other enhancement, but the speed and volume of change that many of our previously referenced agents are encountering points to *adaptability* as a well-suited definition that incorporates the key aspects of our enhancement set and alludes to survival and prosperity as basic metrics. By combining agents at multiple scales and with multiple feedback and feed-forward interactions we create models to explore *systems* of interaction to explore adaptive strategies and capacities. So in addition to helping us ask important development questions, CAS also helps us point towards useful answers. In addition, complex models allow us to explore these issues faster and cheaper while minimizing ethically problematic social engineering and experimentation.

This framework of *development as adaptability* focuses on the basic issue of what constitutes adaptive or evolving behaviors in individuals and groups. Some key insights are suggested by highly dynamic and complex strategies employed by bacterial colonies, the most ubiquitous and diverse collective life form on Earth. Ben-Jacob and others have discovered collective spatial engineering and adaptation in bacterial colonies in response to environmental conditions (2009, p.79). The key techniques for individual bacteria to

coordinate and match structure and task-assignment patterns to growth conditions are collective sensing, information storage and recall, and distributed information processing. It must be noted that network architecture and signaling methods are also key functional supports to these three processes (Ben-Jacob 2003). Taking cues from these highly successful, adaptive biological systems helps to focus contemporary human systemic needs for individual and group development under more intense evolutionary pressures. For communities, responding to ecological, economic, and social pressures places greater and greater demands on their *collective sensing, information collection and distribution, and collective learning and decision-making practices*. These are the fundamental tasks of adaptive planning of complex systems, and these tasks are being transformed in incredible ways through technology. It is vital that the systems put in place to improve our performance in this area be carefully explored as soon as possible to minimize expense, ease social transitions, and maximize beneficial impacts.

The central place these basic functions play for group adaptive behaviors is easily illustrated by many of the questions that may confront individuals regardless of where they live, their abilities, and what their social status may be. Namely: What is happening? What options exist? What are the best options? What needs to be done to achieve subsequent goals? What can I do individually to help achieve the goals? What are the costs and benefits of my participation in these efforts to me, to those close to me, and beyond? What other options for change or stability exist for me personally? In addition to individual answers, these questions are also scalable for groups, communities, regions, nations and so on. As social beings, our collective processes are integrally linked to our individual decision-making. Models can help us design and test approaches to optimize adaptive development, and as this review will show much has already been learned to suggest the direction of future research into both real-world and simulated development systems.

The science of cities

One of the key points for development is the role localities have in fostering and capitalizing on scale advantages, especially for innovation. For Edward Glaeser (1998, p.140), the benefits of cities are directly related from lower transportation costs for

exchanging goods, people, and ideas. He sees the fate of cities as innovation centers depending on a kind of cost-benefit analysis of various incentives and infrastructures like commuting times, rents, schools, access to new skills, and higher wages as opposed to crime, pollution, high costs of living, and long commutes. Because notions about the intellectual utility of cities are based on case studies rather than direct evidence, the role of cities for innovation is difficult to prove. However, Glaeser argues that the productivity and skill gains for urban workers have better statistical support.

Taking things further, Bettencourt and West (2010) have called for a *science of cities* to explore the scaling benefits and detriments of urbanization. They find that as a city size is doubled, it sees increases by about 15 percent more than linear growth for benefits like wages, GDP, patents, and number of educational and research institutions, as well as the same increases in negative costs like crime, traffic congestion, and disease. Building on this, they write that: “Policy initiatives in developed and developing cities should be viewed as experiments that, if carefully designed and measured, can help support the creation of an integrated, predictive theory and a new science of performance-based planning.”

Urban modeler Michael Batty (2013) has also called for a science of cities. He emphasizes that cities are not centrally ordered, but are instead predominantly bottom-up and therefore more evolutionary in their functioning than products of grand designs or plans. Since they are largely characterized by social networks, “The key to understanding how networks fracture and split, how economies of scale and innovations are realized through the way different networks relate, and the ways in which prosperity and the creation of wealth are linked to these network effects, are central questions that our science needs to address” (p. 33-34). For him too, the key issue is scale. Batty sees complex modeling in the ascendency, and he is encouraged that many are focused on how cities function rather than on narrow testable hypothesis geared towards matching a data set. Focusing on these bottom-up, evolutionary functions and how they operate through social network effects forces us to reappraise development theory, especially as it relates to economics and economic modeling.

Evolutionary economics

Before exploring model dynamics specifically, it is important to review relevant theory from evolutionary economic research. Foster (2011), writing from an evolutionary macroeconomic perspective, states that since economic systems are complex adaptive systems, economists have found it difficult to construct models of economic growth that can identify the relative impact of different economic drivers such as invention, entrepreneurship, technological and organizational innovation, education, training and experiential learning. Together this means that it is largely *generation of variety* that creates profits and competitive pressures which select for optimal approaches. The fact that these two operations occur simultaneously and mutually affect one another creates the complex behavior of economic systems.

Foster (2011) points to the networks structures and behaviors of economic rules, the *meso-rules* as the key modeling and empirical research goal, pointing to the work of Dopfer and Potts (2009) who define this meso unit in terms of stable rule regime innovations inclusive of group dynamics, routines, and common practices. The macro-levels are larger economic orders and systems equivalent to ecosystems. Micro-levels are individual agents and minds. Using these levels, they define *evolutionary economics* as “the study of the self-organizational process of coordination and of re-coordination of generic rules,” or the knowledge structures of the economic order. Foster provides an example methodology using these theories. First, a meso-rule set must be discovered and connected to relevant data and agent behaviors. For ABM, agents would all obey identified meso-rules, but with varying intensity to reflect agent diversity and allow for subsequent success and failure patterns. This emphasis on behaviors, norms, and expertise, or the social infrastructure, is quite distinct from economic development models more focused on physical infrastructure. According to evolutionary economic theory then, economic emergence is a function of the combined and interactive actions of entrepreneurial groups and individuals, a co-evolving rule structures. Taking this approach further, Foster and Metcalf (2011) incorporate natural systems with entrepreneurship to argue that economic systems as dissipative structures need economic innovation to reduce energy gradients through knowledge, logic, and imagination. By bringing in energy dynamics, environmental distribution and spatial aspects are reinforced as critical variables.

In a literature review of different approaches to economic geography by Fratesi (2010), he critiques what he terms neoclassical economic geography (or new economic geography) in which space is largely abstract and where all actors behave optimally as being too general, and institutional economic geography which he sees as too case specific to be broadly applicable. He advocates his evolutionary modeling as an approach that can both represent the complexity of spatial economic development without oversimplifying it and still formalize concepts in broader terms than is possible with logical argument dependent case studies. His model incorporates both loops and feedbacks in systemic interrelationships of *stocks* and *flows*. The overall structure models local government interactions, learning and human resources, networking, innovation, and indicator and control variables. While the comprehensiveness of the model is an achievement, its complexity is a distinct barrier to answering direct and simple questions. As Martin and Sunley (2011) describe the dilemma, “Of course the high level of abstraction of the various metaphorical notions of emergence means that they do not explain the social processes and interactions through which economic emergence occurs in different ways in different contexts.”

Agent-based models

Moving from general to more specific studies, the literature of agent-based models relating to development has been expanding in recent years. In many cases, these studies contribute to exploring some of the challenges Martin and Sunley (2011) alluded to. As a consequence of moving from rational actor based models for individual behavior found in more classical economic studies, Dawid and Neugart (2011) find that there are many degrees of freedom as to what can be assumed for agent behaviors such as workers, companies, or governments when designing ABM. To select agent behaviors for the EURACE research (Dawid et al. 2008), a large-scale agent-based program for European Economic Policy Design, they adopted behaviors described in corporate management rules and manuals. They also recommend incorporating findings from experimental studies for modeling individual behaviors. In the first of their models for EURACE, they developed a model to study the role of innovation and skills for regional economic growth and employment. Their findings indicate that there is a point where allocating

resources to improve skills equally across regions did improve long run outputs, but that focusing the same amount of spending in one region led to the very worst policy outcome for the model. This first model incorporated high commuting costs in order to isolate the two regions studied.

In a second EURACE study, Dawid et al. (2009) also looked at the general increase of skills of workers in a model regional economy. Based on previous empirical evidence that skill distributions can affect regional speeds of technological change as well as employment and wage growth that can concentrate high-skilled workers in just a few areas, this study modeled dynamics when commuting costs (spatial friction) were much lower than the earlier study. What they found was that the size of the commuting costs had a critical but variable impact on the performance of different policy approaches. For this model with small commuting costs, they found that a more spatially concentrated approach worked better than the earlier cross-regionally uniform skill investments. In their words: “These findings reinforce the point that the spatial distribution of policy measures matters.” Pointing to these findings, they report that the discovery through modeling that spatial frictions can actually be positive in macroeconomic effect is a new discovery in the literature.

Two of the EURACE collaborators, Gemkow and Neugart (2011), created an ABM to examine referral hiring and social networking cost-benefit analysis under different job stability conditions. The model showed that as a response to increased volatility in labor demand, the average number of “friends” declined and the amount of referral hiring dropped from 58 to 40 percent. The mechanism they identify is that as labor demand volatility increases more turnover creates more hiring and those who had been previously crowded out due to few contacts are better able to compete for positions. In addition, agents invested less effort to developing and maintaining contacts since it was more likely contacts would not be available for a referral when needed, thus reducing referrals as a result.

An important ABM by Antonelli and Ferraris (2011) looked at innovation as an emergent property of economic complex system dynamics. For them, innovation is emergent because it occurs when the external conditions and structure of the system provide access to external stimulus (knowledge) critical for feeding the effective

recombination interactions within the system. A number of the model's findings are quite interesting in their policy implications. For example, concentrated distribution of knowledge centers (such as universities, research parks, etc.) performed better in the model for generating discoveries than more distributed patterns, however, broader distribution helped companies more by improving dissemination and adoption of new technology (commercialization). By simulating intellectual property rights regimes, they were also able to show how different restrictions affected innovation within the system overall, as well as subsequent distribution patterns. Their findings suggest that despite the need for the profit incentives protections provide, the longer intellectual property protections lasted, the slower new technologies could spread among firms. They suggest compulsory royalty payments and reduced length for patent protections to allow firms to both profit from their discoveries and benefit quickly from the discoveries of others.

As a last example of ABM applications for development research, Celik et al. (2012) create a simulation in which workforce assignments for software development projects are selected by a "Decision Evolution Procedure." Drawing on position metrics to identify key individuals from specific parts of the organization's overall internal social network, workgroup members were identified to maximize group productivity, training, and robustness in the face of possible worker turnover through a two-tiered process. The first, or evaluation module, calculated the position value between various pairs of workers on such parameters as trustworthiness, reputation, and proximity. An algorithm is applied to evaluate the relative standing of workers within the network (who people were connected to as a proxy for what information they had access to). For the second or assignment module, workers are selected using an ABM simulation to optimize workforce ratios from the evaluation model for that specific project. Though its applicability and efficacy beyond simulation conditions are not firmly established, this simulation raises many important issues for development studies. Firstly, the automation of workgroup assignments within organizations is of concern for worker freedom and choice without adequate safeguards. The potential harm and abuse of such a system are easy and alarming to imagine if it were used to manipulate or exclude. That said, however, the capacity to apply modeling and simulation technologies to identify, assign, and coordinate working teams could be a breakthrough for the three capacities—collective

sensing, information availability and sharing, and collective learning and decision-making—identified by Ben-Jacob (2009) as important for adaptive group development.

Case studies

While the science of cities, evolutionary economics, and agent-based modeling research have reflected different approaches to applying complexity and development, much of the development literature does not include complexity in its analysis nor does it seek bottom-up processes in its research variables. Despite this, the data collected and patterns identified in the empirical literature of small businesses, entrepreneurs, and employment dynamics can be of critical importance for designing models that reflect or capture actual emergent patterns. Surprisingly, reliable research on such basic topics as small business development patterns is relatively recent and incomplete, due to a lack of data and academic interest until the 1980s and 1990s.

Now, with more global data sets and comparative studies available, some discoveries have been made. In a broad overview of these findings, Acs et al. (2008) report that there is strong evidence that the global economy reflects three stages of economic development: a factor-driven stage where low-cost production and value-added activity is marked by many small businesses, the efficiency-driven stage where production improvements and economies of scale decrease self-employment, and the innovation-driven stage which sees an increase in entrepreneurial activity associated with service firms. From a practical standpoint, this means that bottom-up models of economic development must take the larger economic development contextual stage of the economy into account, as small businesses and operations are not always appropriate to local or national conditions.

As an example of how a locality can move from efficiency-driven structures to innovation-driven institutions when decline has occurred due to shifting economics associated with stage change, Comunian (2011) studied some of the development strategies of Newcastle, England, as it has slowly built a nationally prominent arts scene in a former industrial region. Unlike Acs et al. (2008), her case study applies complexity theories as well, with a focus on the learning processes and micro-dynamics which she characterizes as collective responses to changing conditions. Using a collection of

interviews and social network data, Comunian argues that cultural development in a city requires cultural infrastructure and networks more than flagship architectural infrastructural development to be successful. However, she also cautions that while complexity theory reveals important interactive dynamics, it does not provide a recipe for success due to different contextual conditions, so attention must be paid to existing local assets and interactions.

These findings are echoed by Sean Safford's (2009) comparison of the economic development trajectories of both Youngstown, Ohio and Allentown, Pennsylvania. When studying the cities, he discovered that Allentown did a much better job of incorporating key economic leaders back into the community during times of economic stress, whereas in Youngstown stress created social engagement vacuums as key players looked to their own interests and organized crime seized the opening to take over the community. Safford notes that Youngstown's leadership concentrated on personal goals rather than collaborating with other company leaders towards city-scaled strategies. Based on network theory applications, Safford argues that various forms of social networks shape regional decision makers' ability to form coalitions and coordinate under crisis conditions (p. 137). Safford's findings and methodology have very broad importance because it shows that one of the most critical things for urban development is creating a robust social structure by understanding where critical linkages do and do not exist in their localities so they can take steps to forge better ties across the strategically important disconnects in their communities (p. 139).

Sociologist Robert J. Sampson (2011, p. 47) expands on these points in his research of neighborhood effects in Chicago, particularly in distressed communities. To him, *neighborhood effects* are in part "social-interactive processes that involve collective aspects of community—emergent properties, in other words," reflective of *contextual causality*. While never addressing complex systems directly, his language is highly similar. Another emergent property Sampson sees at work is his concept of *collective efficacy*, or informal social cohesion, shared expectations, and everyday strategies for addressing challenges, which are fundamental to communities that are improving local well-being (p. 368). Interestingly, collaborative problem-solving is often predominantly triggered by a shared perception of threats. This case study is especially

significant for reaffirming the potential for improved results if the collective sensing, information collection and sharing, and collective learning and decision-making architecture are functioning well.

Networks, diversity, and informatics

Modeling researcher Scott Page (2011; see also 2007) has written on the critical importance that diversity and the structure of participation have on the overall outcome of system robustness, adaptation, and group decision-making. By utilizing what he terms *cognitive diversity*, which describes the ways people think about problems by drawing from identity, experience, education, training and interests, he has shown that diverse groups perform better at a large number of cognitive tasks when utilized as a complex adaptive system. Page has found group complex systems often include specialization, responsiveness, and competitiveness and several forms of synergies like collective knowledge, redundancy, degeneracy, modularity, and crosscutting cleavages (2011, p. 247 - 248). For him, models are valuable because they allow a formal analysis of the effects of diversity, which is something that has largely been missing or inadequate from previous development research. However, he cautions that “Learning what types of diversity to encourage or introduce into a particular system will require data, information, knowledge and wisdom of how that system operates” (p. 254).

Goldstone et al. (2008) have taken steps in this direction by using ABM to research the link between goals, beliefs, and cognitive capacities of individuals and subsequent group behaviors in order to show how innovations diffuse and resources are allocated. By manipulating the kinds of information agents had access to, their results showed that different kinds of networks performed better at different kinds of problems, including the really surprising result that more locally focused social networks were better at solving difficult problems (p. 14). This bodes well for local economic development efforts if networks can be optimized and directed at the right questions. Kelliher et al. (2009) studied a tourism small-business network in Ireland and found that network relationships and business mentors were identified by participants as the most required support structure for success.

But how is all this complexity, diversity, networking, modeling, and planning to be practically planned and built given all the nuanced, case-specific, and path-dependent challenges of adaptive development? According to Barrett et al. (2011), the co-evolution of local network interactions emerge from individual decision-making processes, which requires a clear systematic model to understand. The modeling and network demands for these efforts are broad, but the factors involved are familiar:

- a) “support for multiple views and multiple optimization criteria, for the multiple stake-holders (adaptability);
- b) the capability to incorporate multiple sources of data (extensibility);
- c) the capability to model very large, interacting network systems (scalability); and
- d) support for policy planning by allowing evaluation of a large class of possible interventions (flexibility)” (p.3).

As development planning moves towards the goal of adaptive processes, information science move more and more to the foreground with the approach becoming *policy informatics*, which has been defined as “how tools, models, and simulations are used to aid individuals and groups make informed policy choices” (Johnson et al. 2007). As Allen et al. (2010, p. 10) argue, there is also a constant danger of optimizing an existing system that is best-suited for fleeting moments of stability or benevolent conditions. They argue that what is needed is a reflexive analysis and modeling procedure to explore different and novel situations, and various approaches to deal with outcomes (p. 16).

Despite the high technology and high complexity of these challenges, many urban theorists from a host of disciplines seem to be saying that we are only rediscovering and refining the main functional dynamics of community. Nikos Salingaros (2012; see also Coward & Salingaros 2004) has described cities as information architecture systems. He blames many of the problems associated with current development patterns on formal planning processes that imposed one-size-fits-all solutions on variable environments and contexts that he describes as completely lacking the organizational structure needed to support essential adaptation. As an antidote, he recommends a return to “traditional” interactive or *computational* development methods which yielded hierarchical power-law patterns at every scale of an urban environment. Historically, most urban interactions

were very small-scale, very local, and highly information rich. Understanding such adaptive relationships for local economies as complex systems may be another critical direction for further research and modeling

Conclusion

As is apparent from this review, the possibility of an adaptive development methodology is still a work in progress. Though considerable ground has been laid in a host of disciplines, the search for models capable of capturing both the complexity and specificity of adaptive development is only beginning, or perhaps *emerging*. There are few efforts to combine these disparate threads in real and virtual systems into a basic framework so that models, theories, and case studies reinforce one another and narrow the parameters of uncertainty for critical development tasks. Key interactions like feedbacks and network architecture appropriate for this new direction have not yet been sufficiently described from data. However, by focusing on collective information development and collective sensing, learning, and decision-making, it is argued that an overtly intentional system for adaptive development can be modeled, refined, and tested.

In addition to local contexts, the constant role of change for determining contemporary urban economies must also be accounted for within development research. By incorporating emerging complexity theories and modeling tools towards a recursive data, assessment, model, data, assessment, and exploration pattern of research and application as Allen argues, systemic features and outcomes can be structured and restructured over time. For urban development, the means of adapting development processes and planning over time to utilize complexity can move into view. Bringing these research enterprises closer together is a key task for urban development planning.

References

- Acs, Z. J., Desai, S., & Hessels, J. (2008). Entrepreneurship, economic development and institutions. *Small Business Economics*, 31(3), 219–234.
- Alberti, M. (2008). *Advances in urban ecology: integrating humans and ecological processes in urban ecosystems*. New York: Springer.
- Allen, P., Varga, L., & Strathern, M. (2010). The evolutionary complexity of social and economic systems: The inevitability of uncertainty and surprise. *RISK MANAGEMENT-AN INTERNATIONAL JOURNAL*, 12(1), 9–30.
- Antonelli, C., & Ferraris, G. (2011). Innovation as an Emerging System Property: An Agent Based Simulation Model. *Journal of artificial societies and social simulation*, 14(2).
- Barrett, C. L., Eubank, S., Marathe, A., Marathe, M. V., Pan, Z., & Swarup, S. (2011). Information Integration to Support Model-Based Policy Informatics. *The Innovation Journal: The Public Sector Innovation Journal*, Volume 16 Issue 1, 2011. Retrieved from <http://www.innovation.cc/volumes-issues/vol16-no1.htm>
- Batty, M. (2005). *Cities and complexity: understanding cities with cellular automata, agent-based models, and fractals*. Cambridge, Mass.: MIT Press.
- Batty, M. (2013). *The new science of cities*. Cambridge, Massachusetts: MIT Press.
- Ben-Jacob, E. (2003). Bacterial self-organization: co-enhancement of complexification and adaptability in a dynamic environment. *PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A-MATHEMATICAL PHYSICAL AND ENGINEERING SCIENCES*, 361(1807), 1283–1312. doi:10.1098/rsta.2003.1199
- Ben-Jacob, Eshel. (2009). Learning from Bacteria about Natural Information Processing. *Annals of the New York Academy of Sciences*, 1178(1), 78. doi:10.1111/j.1749-6632.2009.05022x
- Bettencourt, L. M. A., Lobo, J., Strumsky, D., & West, G. B. (2010). Urban scaling and its deviations: revealing the structure of wealth, innovation and crime across cities. *PloS one*, 5(11), 13541.
- Bettencourt, L., & West, G. (2010). A unified theory of urban living: it is time for a science of how city growth affects society and environment. *Nature*, 467(7318), 912.
- Celik, N., Xu, D., Son, Y.-J., Lemaire, R., Provan, K., & Xi, H. (2012). Simulation-based workforce assignment considering position in a social network. *SIMULATION*, 88(1), 72–96.
- Chaturvedi, A., Mehta, S., Dolk, D., & Ayer, R. (2005). Agent-based simulation for computational experimentation: Developing an artificial labor market. *European journal of operational research*, 166(3), 694–716. doi:10.1016/j.ejor.2004.03.040
- Clancey, W. J., Sierhuis, M., & Seah, C. (2009). Workflow agents versus expert systems: Problem solving methods in work systems design. *AI EDAM*, 23(4), 357–371.
- Comunian, R. (2011). Rethinking the Creative City: The Role of Complexity, Networks and Interactions in the Urban Creative Economy. *Urban studies (Harlow)*, 48(6), 1157–79.
- Coward, L., & Salinger, N. (2004). The Information Architecture of Cities. *Journal of information science*. 2004; 30:107-118.

- Dawid, H., Gemkow, S., Harting, P., Kabus, K., Wersching, K., & Neugart, M. (2008). Skills, Innovation, and Growth: An Agent-Based Policy Analysis. *JAHRBUCHER FÜR NATIONALÖKONOMIE UND STATISTIK*, 228(2-3), 251–275.
- Dawid, H., Gemkow, S., Harting, P., & Neugart, M. (2009). On the Effects of Skill Upgrading in the Presence of Spatial Labor Market Frictions: An Agent-Based Analysis of Spatial Policy Design. *Journal of artificial societies and social simulation*, 12(4), A67–A89.
- Dawid, H., Gemkow, S., Harting, P., & Neugart, M. (2009). Spatial Skill Heterogeneity and Growth: An Agent-based Policy Analysis. *Journal of artificial societies and social simulation*, 12(4), 5.
- Dawid, H., & Neugart, M. (2011). Agent-based Models for Economic Policy Design. *Eastern Economic Journal*, 37(1), 44–50. doi:10.1057/eej.2010.43
- Dopfer, K. and Potts, J. (2009). On the Theory of Economic Evolution. *Evolutionary and Institutional Economics Review*, 6, 23–44.
- Epstein, J. M. (2006). *Generative social science: studies in agent-based computational modeling*. Princeton: Princeton University Press.
- Epstein, J. M., Axtell, R., & 2050 Project. (1996). *Growing artificial societies: social science from the bottom up*. Washington, D.C.: Brookings Institution Press.
- Foster, J. (2011). Evolutionary macroeconomics: a research agenda. *Journal of Evolutionary Economics*, 21(1), 5–28.
- Foster, J., & Metcalfe, J. S. (2011). Economic emergence: an evolutionary economic perspective. *Journal of economic behavior & organization*. doi:10.1016/j.jebo.2011.09.008
- Fratesi, U. (2010). Regional innovation and competitiveness in a dynamic representation. *Journal of Evolutionary Economics*, 20(4), 515–515–552. doi:10.1007/s00191-009-0169-1
- Gemkow, S., & Neugart, M. (2011). Referral hiring, endogenous social networks, and inequality: an agent-based analysis. *Journal of Evolutionary Economics*, 21(4), 703–719.
- Glaeser, E. L. (1998). Are Cities Dying? *The Journal of Economic Perspectives*, 12(2), 139–160. doi:10.1257/jep.12.2.139
- Goldstone, R. L., Roberts, M. E., & Gureckis, T. M. (2008). Emergent Processes in Group Behavior. *Current Directions in Psychological Science*, 17(1), 10–15. doi:10.1111/j.1467-8721.2008.00539.x
- Johnston, E., Kim, Y., & Ayyanger, M. (2007). Intending the Unintended: The Act of Building Agent-based Models as a Regular Source of Knowledge Generation. *Interdisciplinary description of complex systems*, 5(2), 81–91.
- Kelliher, F., Foley, A., & Frampton, A.-M. (2009). Facilitating small firm learning networks in the Irish tourism sector. *Tourism and hospitality research*, 9(1), 80–95. doi:10.1057/thr.2008.36
- Martin, R., & Sunley, P. (2007). Complexity thinking and evolutionary economic geography. *Journal of Economic Geography*, 7(5), 573–601. doi:10.1093/jeg/lbm019
- Martin, R., & Sunley, P. (2011). Forms of emergence and the evolution of economic landscapes. *Journal of economic behavior & organization*. doi:10.1016/j.jebo.2011.08.005

- Page, S. E. (2007). *The difference: how the power of diversity creates better groups, firms, schools, and societies*. Princeton: Princeton University Press.
- Page, S. E. (2011). *Diversity and complexity*. Princeton, NJ: Princeton University Press.
- Portugali, J. (2011). *Complexity, cognition and the city*. Berlin: Springer.
- Railsback, S. F., & Grimm, V. (2012). *Agent-based and individual-based modeling: A practical introduction*. Princeton: Princeton University Press.
- Safford, S. (2009). *Why the garden club couldn't save Youngstown: the transformation of the Rust Belt*. Cambridge, Mass.: Harvard University Press.
- Salingaros, N. (2012). Urbanism as Computation. In J. Portugali, H. Meyer, E. Stolk & E. Tan, Eds., *Complexity Theories of Cities Have Come of Age*, Springer, Berlin: pages 247-270.
- Sampson, R. J. (2011). *Great American City: Chicago and the enduring neighborhood effect*. Chicago; London: The University of Chicago Press.
- Schelling, T. C. (1978). *Micromotives and macrobehavior*. New York: Norton.

Chapter 3: A Grounded Theory of Urban Network Development Functions

Introduction

As people move through their day-to-day lives they are exposed to various forms of place-based economic behavior signals. These signals, like shopping, selling, making, or service activities, are social exchanges that can draw others' attention towards or away from certain products or services. Some commercial information signals, like sales activity, are potentially observable to anyone watching a trade between a buyer and seller in stores or marketplaces. Because of spatial *boundaries* where such exchange signals are detectable (Holland 2012), specific locations and environments are the delivery devices for important economic behavior signals for much of the development activity across an urban system's multiple sites and scales.

As many economic signals are spatially mediated, delivered, and contained in specific environmental settings at specific scales, spatial settings effectively organize opportunities and constraints on behavior (Stokols 1981). It is the exchange of social, financial, and environmental signals, enacted at specific times and locations that create, or generate, urban and regional development patterns through market activity and social networks. Facilitating urban environmental design and planning to better support economically useful signal production and exchanges towards enhanced value creation, participation, and equity distribution outcomes is a fundamental challenge for many locales. To best organize, support, and design settings for economic behaviors in urban space, urban development theory needs an inclusive framework to identify and assess urban economic behavior settings individually at neighborhood scales as well as in terms of overall distribution patterns throughout an urban system.

Economic development has been defined as the expansion and advancement of capacities and potential of individuals, firms, and communities (Feldman et al. 2016, p. 10). With this definition, the multiple overlapping scales of individual human development, business development, and community development are inherent to urban capacities for social advancement. *Urban development* includes these three aspects of economic development as well as the physical site aspects and structuring of specific

connections and services to deliver many of the inputs of human and commercial development, particularly through the spatial organizing of urban community life.

By identifying and analyzing examples of different physical site patterns and the ways they can affect perceiving economically useful social observations, interactions and signal exchanges, or *network functions*, it may be possible to better connect people to one another and their environments in specific ways likely to lead to enhanced network activity supportive of better development outcomes. Examining urban data in this way can ground theory of how physical network infrastructures spatially develop local network forms of nodes, edges, and flows that facilitate or inhibit economic development. By analyzing network structures and land use that determines where, when, how, and at what density development happens, then social contact rates, business information access, and other behavioral cues important for future business development can be better organized and understood in turn.

Study Purpose and Research Question

At the regional or urban system macro-level, Bettencourt (2013) has recently quantified general patterns of development in urban form according to *universal scaling rules*. These scaling indicators of urban economic performance according to labor region population size help to evaluate matters of infrastructure networks and correlated elements of productivity, transportation, energy, and associated financial costs. Since these built infrastructure networks are fundamental to overall regional costs and urban capacity, network evaluation of the overall system efficiency is an important analytic effort. They can show how well-balanced congestion and sprawl challenges are in regions of similar size for example.

However, despite such regional scaling discoveries as Bettencourt's (2013) universal scaling rules, effective local development strategies within different parts of a region remain elusive. Economists, and subsequently policy-makers, have theorized and applied policy experiments to neighborhoods for generations to stabilize economic performance. Many of these, such as local economic development incentives, are often ineffective (Betz et al. 2012). At the national level, debates often center on how to properly either enable wealth accumulation or distribute it. Even as some modern

economists have questioned the basic competence of their field to “produce prosperity” (Holcombe 2013), others have pointed to how historically--and hence systemically--consistent inequality and wealth concentration can be over time (Picketty 2014). Thus at the regional level productivity is characterized in broad network efficiency terms, but street-level intergenerational poverty in many communities reveals very different human-level patterns whose dynamics are less well understood or defined in physical network terms. As Sampson (2012, p.377) writes, “Spatial network flows among neighborhoods are like rivers, with strong currents and whirlpools of activity. The flows of movement and the ways in which neighborhoods are linked together are relational and not something that individuals may be aware of or may easily control.”

This socio-spatial network system needs a better-integrated model of contemporary built form with development theory to facilitate further research. This also contributes to the better design of urban space to support or contribute to commercial emergence and wealth creation, largely through clarifying spatial and environmental impacts on behavior. These urban behavioral impacts could include social dynamics, market perception, resource access and proximity, labor experience, and business experimentation forms and distributions.

In basic development terms, spatial networks are essentially delivery devices for people and the things they need to live (like energy) and organize themselves (like information and relationships). Communication and informational technologies are making the spatial positions of vast stores of information increasingly flexible. But inescapably, a person’s interactions with information, no matter how high technology its delivery device, is always in a human body in a human environment somewhere, and this has important implications for urban design (Misra and Stokols 2012). Furthermore, environments provide their own information signals which can function to influence or organize human behavior in ways that affect social network dynamics (Wicker 1979). This is especially true of interpersonal environments which can facilitate face-to-face communication for decision-making (Pentland 2008), as well as connect the people, technologies, and information that coevolve to form markets (Beinhocker 2006).

Culture too has spatially generated characteristics, as cultural ecosystems require particular locations in time and space to exist (Low et al. 2005, p. 5). Social relationships

are facilitated by proximity and constant interactions if facilitated by perceived homogeneity and mutual needs and reciprocity (Michelson 1970). However, in conditions where residents keep to themselves rather than interacting—whether for social or environmental reasons—hardly any sense of community can emerge (Appleyard 1981). This has enduring implications for the development functions of interacting networks of individuals, groups, and urban sites.

This grounded study of urban development attempts to better integrate urban system spatial network theories with urban design theories and local economic theories as demonstrated through an urban case study. Before local market and socially-constructed features of business development can be properly defined and connected, the overall socio-spatial network system must be properly framed and condensed to provide unified points of reference and theory. Therefore, the specific question pursued is *which spatial characteristics of streets, community sites, and environmental signals categorize local development network activity within the City of Roanoke, Virginia?*

The next section reviews the grounded theory approach in the context of coevolving network theory. The case study and research methods section introduce the City of Roanoke, urban network and commercial data, land use data, and network functional condition evaluations. With the data introduced, categorical frameworks for framing network functions for local development are discussed with relevant literatures. The concluding section summarizes research directions for economic development suggested by the theoretical framework and literature, in order to facilitate better-integrated studies of physical and other development networks at a variety of urban scales.

Grounded Theory and Coevolving Networks

Over the years, substantial research has generated substantial development data which does not relate well across methodologies and disciplines. A network approach to capture and relate data through broader theoretical relationships is an ongoing process of exploration. Grounding a theory to integrate spatial network components and development factors like social dynamics requires looking carefully at the data in order to identify common themes which can be coded into conceptual categories to build better

research and theory. Grounded theory is an inductive rather than positivist approach that attempts to add greater theoretical coherence by identifying novel theoretical connections among the data to enable research question testing in subsequent research (Charmaz 2006). Given the scope of urban research, efforts to integrate different categories into a common theoretical framework is expanding grounded theory in the urban literature (Heacock & Hollander 2011, see also Raparathi 2014). Of course, categorization and theory testing are especially difficult when the variables are distributed across an entire city, and the varying scales from street to region must be tied together. Also, many of the variables are mutually dependent, or *coevolving*, meaning variables exhibit different behaviors in different system settings, times, and scales.

Physical environments often define certain parameters for behavior, and maintaining a common focus on physical contexts across the *spatial* network of streets and sidewalks provides a common integrative data structure for the many non-physical elements and dynamics such as *social* network activity. The goal is to use data organized across a city's spatial network that can eventually incorporate both systemic network analysis and site analysis at the human perceptual scale of the street. This is to better define, organize, and to literally *ground* social, informational, and economic networks within an urban community along this physical urban fabric network, which has the added advantage of being relatively stable and enduring.

Case study and research methods

In order to advance and ground an appropriate development network theory, this case study uses a mixed methods data collection approach. The entire city is introduced and analyzed before then zooming to neighborhood and street areas of particular interest to explore physical characteristics. In order to collect data that can shed more light on what individuals and groups need to get access to development opportunities and sites in communities, the study first focuses on the transportation network overall and then shifts to areas with commercial buildings with higher potential economic activity potential.

Quantitative analysis of the integrated urban street and building network was conducted utilizing a geographical information system (GIS) and urban network analysis tool (see Sevtsuk & Mekonnen 2012) to identify locations with greater or lesser levels of

building connectivity to the surrounding urban fabric. Once candidate development sites were identified, specific case sites were selected, observed during site visits, and assessed for development signals like business density and site conditions. Specifically, qualitative analysis of zoning data confirmed commercially dense and accessible locations, and then site visits followed to identify or validate levels and characteristics of business activities and vacancies, site amenities like street furniture and plantings, traffic speeds, facade condition, and the characteristics of open green space, parking, and sidewalk interfaces. These observations were used to indicate the development dynamics as spatial networks influencing socio-economic networks. The data and methods are explained in more detail as they are introduced.

Introducing Roanoke

The City of Roanoke, Virginia is a well-suited subject for a case study due to several factors. As a city with just under 100,000 people remote from larger more metropolitan areas, its local development is neither too large or metropolitan to study as a whole, nor too small for the extensive study of a variety of different urban neighborhood economic land uses and connectivity. The design of the city shows historical legacies typical of many regional cities including public housing, urban renewal, and urban expressways that caused extensive social pattern disruption (Silver 1987, p.379). Importantly, subsequent to this history, Roanoke now confronts diverging thriving and distressed urban communities, damaged inter-community cooperation and conflict stemming from the racial legacies of urban renewal evictions and segregation, and social consequences of isolated communities bounded or eviscerated by limited access highways that are all too common as urban development challenges across the country (Fullilove 2004). Furthermore, workforce transformations have reduced employment opportunities in many local areas. The physical limitations and transformations of many commercial spaces throughout the city continue to bear witness to these historical legacies.

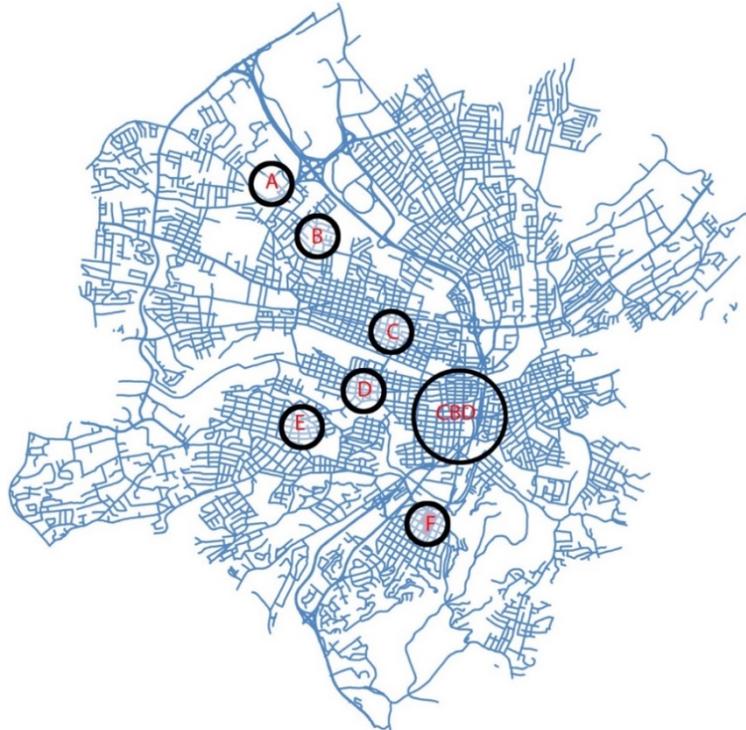
The majority of Roanoke's growth occurred in the late 19th and early 20th centuries, when it became a major rail and, subsequently, a major interstate highway hub. The eponymous Roanoke River carved the lowest east-west gradient in that region of the

Blue Ridge Plateau, making it uniquely ideal for railroad access into the Southern Appalachian Mountains. The river valley also connected to a major north-south route extending down the Shenandoah Valley which had been a major transportation route for centuries. The crisscross of commerce in coal, lumber, and other commodities east and manufactured products west led to a boom in growth so fast that one of Roanoke's monikers became "the magic city." A century later, global transportation patterns and corporate relocations have forced Roanoke to try to redevelop and transition much of its economy and many of its communities to recapture that former economic magic.

Urban network and commercial center data

The case study project area initially included the entire City of Roanoke (See Map 1 below), and quantitative and qualitative analysis of geographical information system (GIS) data provided by the City staff as well as business data from the local regional planning district, Roanoke Valley-Alleghany Regional Commission. The network conversion process utilized MIT's Urban Network Analysis (UNA) toolbox for ArcGIS (see Sevtsuk & Mekonnen 2012). The UNA toolbox transforms a GIS map of Roanoke's streets and buildings into a network graph where nodes are street intersections and streets were network edges. Additional nodes were defined by the center point of building locations. This network graph was then mathematically evaluated to quantify the level of accessibility of the entire city's buildings as weighted by their ground floor footprint area.

Specifically, buildings were evaluated to see the number of times they were situated along the shortest path between pairs of nearby buildings within a standard ten-minute walking range of a 600-meter *search radius*. This *betweenness centrality* measure serves to estimate potential or likelihood of traffic along different parts of a network, perhaps on their way to somewhere else.



Map 1: A street network map of the City of Roanoke, Virginia. Sites discussed include the central business district (CBD), A. Hershberger Rd, B. Cove Rd, C. 11th St, D. West End, E. Grandin Village, and F. Crystal Springs St.

Transportation network analysis like this can use graph theory to answer requirement questions about the appropriate number of objects in a network, the best locations for those objects, and how users or activities should be allocated to facilities. Additionally, depending on the key operating constraints, network analysis can also be used to minimize maximum distances for a facility like emergency services or minimize average distances for configurations of a limited number of facilities (Larson & Odoni 1981). Since betweenness centrality is a metric for understanding the likelihood of someone traveling on an edge from different points of a network, it is a key measure of potential customer contacts for businesses and commercial buildings (Hillier 2012). Betweenness scores also inherently improve with walkable distances and higher densities of alternative destinations along a route (Sevtsuk & Mekonnen 2012).

The UNA toolbox also supports a number of additional network metrics to betweenness, including *reach*, *gravity index*, *closeness*, and *straightness*. UNA reach centrality index measures the number of destinations to a location point within a given

search radius. This measure could potentially tell you how many buildings or residents are within that radius, allowing analysis and comparisons to maximize particular densities or demographics. Like reach, a gravity centrality index measures spatial accessibility within a radius, but with the potential for distance or time cost weighting calculations for more realistic transport measures. Closeness centrality index is useful for measuring how close a building is to all other buildings within a radius. The straightness index is a ratio between Euclidian distance and geodesic distance from each location in a radius to surrounding locations. Straightness reflects which locations offer the most direct travel to their neighbors (often along major thoroughfares) as a result of longer and straighter travel routes (Sevtsuk & Mekonnen 2012).

Based on Roanoke land use zoning, key study areas initially included all commercial sites outside the downtown central business district (CBD). Offices and businesses in the Roanoke CBD are at the core of many of Southwest Virginia's banking, governance, health, and other regional economic administration and functions. However, the skyscraper morphology and regional commuting patterns are categorically more distinct and dense economic land uses and morphologies than the remainder of Roanoke's urban fabric which have very different network characteristics and dynamics. More importantly, the office, commercial, and residential spaces of downtown have different network development opportunities due to overall density, the higher costs per acre of land, and the greater integration of transportation to the rest of the city (see Map 2 below). Furthermore, restricted public access to sites like many downtown office buildings creates barriers to new networks and contacts than would otherwise be indicated by betweenness measures. A downtown's interactive socio-economic potential is rightly a point of focus for the city's future development, but mainly for bigger scale enterprises or in buildings well designed to interface with sidewalks and streets.



Map 2 A: West downtown Roanoke in yellow and surrounding buildings (left). The 11th St. Corridor is upper left in purple. Scale 1: 8000. B: Central downtown building footprint densities and paved areas (right). Scale 1:4000.

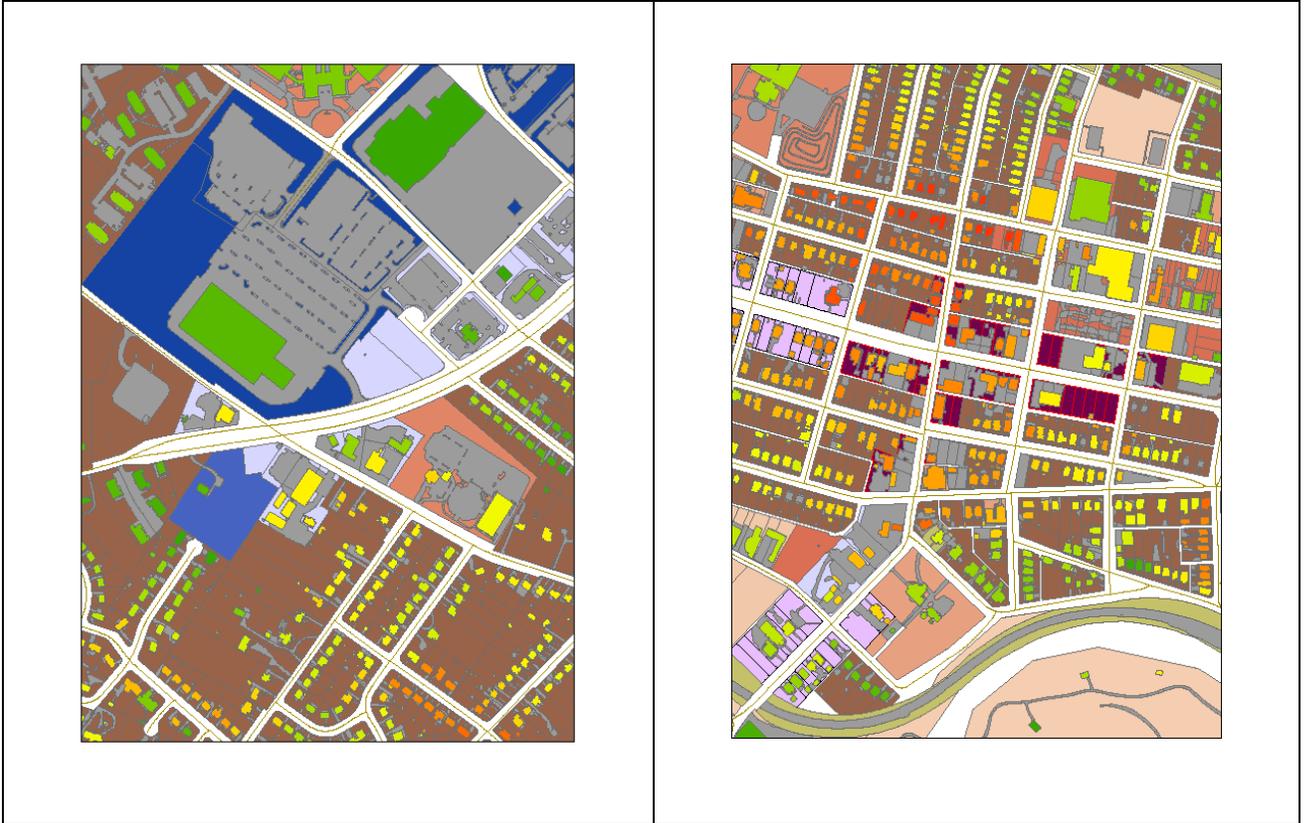
As a demonstration of outlying site betweenness, Map 3 (below) shows a color-coded map of building area footprints in the Grandin Village area of Roanoke. The officially designated Commercial Neighborhood (CN) zoned lots appear in purple with the darker red and orange buildings, particularly the larger commercial buildings, indicating a higher betweenness centrality level than many of the smaller houses. Commercial building sizes have an important impact on the scope and rental costs of business, and getting the right fit is a fundamental small business task. A diversity of building sizes facilitates a more appropriate supply to choose from and may allow moving for expansions and reductions as needed. This community exhibits an extremely strong balance of residential to commercial buildings, diverse building sizes, diverse commercial building uses, and a large number of enterprises overall. This means that the

network betweenness centrality easily facilitates flows of people for a variety of social, economic, and transportation purposes.

Map 3 A: Betweenness Centrality of Grandin Village (left). B: Betweenness of 11th Street (right). Scales 1:4000. Red indicates high, yellow moderate, and green poor building betweenness centrality. Gray indicates surfaces such as parking lots and railroads. Purple is open space.



By contrast, another CN zoned site along the 11th Street corridor (Map 3B) shows lower betweenness levels despite a large number of business lots. The number of vacant lots in both commercial and residential lots detracts from the inter-building network continuity of both. Ironically, despite this uneven building density, 11th Street is within blocks of downtown. Unfortunately, further signs of network distress are evident not just in vacant lots, but also in empty buildings.



Map 4 A: Betweenness Centrality of Hershberger Rd (left). B: Centrality of West End (right). Scales 1:4000. Red indicates high, yellow moderate, and green poor building betweenness centrality.

Most of the commercial zoning types in Roanoke (not downtown, CN, or mixed use) include shopping centers, strip malls, or nearby high-traffic multi-lane commercial boulevards that are difficult and dangerous for pedestrians. These areas are car-centric in design and poorly accessible from the nearby residential areas, so enhancing strong social network opportunities for interaction would require complete transformations of the urban form to low speed, higher density urban fabric to support social encounter rates. As we see in Maps 4 above, more car-dependent shopping areas had the lowest betweenness centrality measures as well. They represent poor new business generation sites due to their high relative rental demands and costs in acreage, greater infrastructure investment and transportation services for the public, and their low density/low-quality social interaction environments.

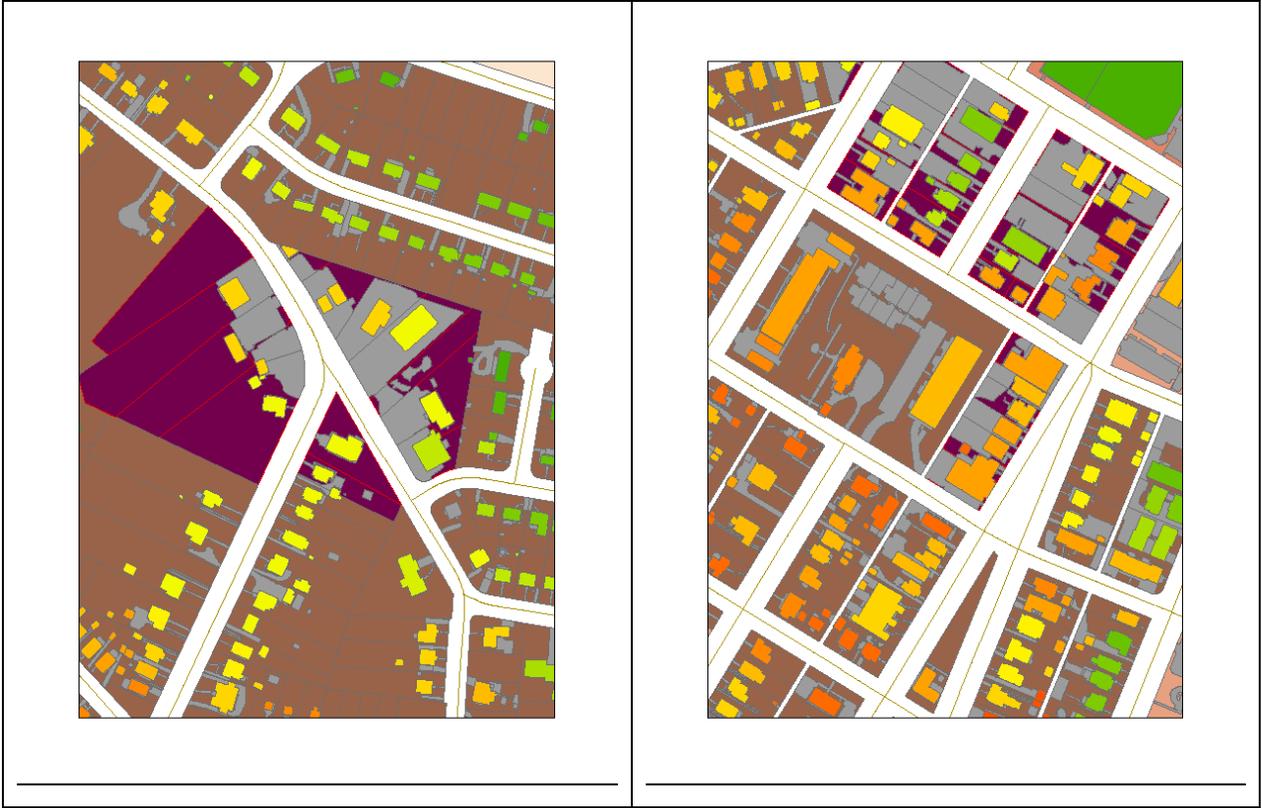
Land use data: (Building area, vacancies, open spaces, pavement, current functions)

The degree to which a commercial area can support specific economic activities and public life varies; some physical attributes will facilitate socio-commercial interaction, and others will reduce it (see Table 1 below). Zoning can tell us where most commercial activity is allowed. Betweenness centrality and zoning together can indicate urban network densities supportive of economic contacts with potential customers and clients. More people moving through such areas can do more things, especially commerce. The next spatial data of interest for development involves the specific land use components within each site that can potentially support activities important for early business formation. The most general uses of commercial urban fabric at this level include buildings, parking, open space, and the active businesses and building vacancies in an area. The businesses data is important at this level of analysis because not all buildings are suitable for all uses whether due to size, infrastructure, or other programmatic requirements. The same is true of open spaces and parking, which can potentially host a variety of uses from parks, open air markets, recreation, and festivals to deliveries, bike and pedestrian pathways, and outdoor restaurant seating, respectively. However, at this level, a basic inventory provides information about key land use parameters and densities that are important for clarifying a network center's internal flow organization and capacities at the building- and street-level scales.

Of those CN areas not downtown or along car-centric thoroughfares, less than ten showed much business and commercial building density or potential for social density, as indicated by available vacant buildings and lots observed during field visits. Further exploration of site morphology and particular land uses provided more useful data on network connectivity and the suitability of each commercial center to support activities and flows potentially important for development. The qualitative measures were of observable social support capacities rather than direct observation of specific human behavior. In other words, a sidewalk indicates a capacity for pedestrians which may or may not be utilized by residents, while the lack of any discernable path is taken as evidence that pedestrian capacities are lacking. Likewise, the presence or absence of street furniture, public green or open spaces, parking lots, vacant buildings or lots, a mix

of building sizes, and business types were observed as data of overall capacities to support different potential land use activities in that area.

Table 1: Urban design indicators of social-commercial contact spatial network distribution		
<i>Commercial Development Variable</i>	<i>Social Contact Generator Indicators</i>	<i>Social Contact Inhibitor Indicators</i>
Commercial Zoning	Residential & business integrated, walkable	Commercial single use, car access dominant
Building density	Higher betweenness centrality	Lower betweenness centrality
Morphology	Urban village; mixed use;	Low-density box stores, malls & shopping boulevards
Parking	Lot scale and position minimized	Lot scale spatially dominant
Business types	Small & medium enterprises	Large and/or retail franchises
Building sizes	Small to moderate square footage	High square footage
Walks & paths	Sidewalks & crosswalks functional and safe	Missing, damaged, or exposed to high-speed traffic
Recreational amenities	Open & public spaces	Missing or exclusive use
Outdoor seating	On or visible from walks	Missing or shielded from walks
Green space & plantings	Attractive & maintained	Barren or rundown
Street furniture	Benches, fountains,	Missing or broken
Building façades	Attractive & maintained	Barren or rundown



Map 5: Land use and urban fabric of Cove Rd (A-left) and Crystal Springs St. (B-right). Scales 1:2000.

Two sites in particular, Grandin Village and Crystal Springs, showed considerable current commercial and land use strengths, and two showed less site potential (Cove and Penmar areas) in terms of number and quality of building stock and overall land use morphology. For example, the land uses of the smaller Cove Road area seen in Map 5A (above) reveal only a limited number of buildings with average levels of betweenness. The road is wide and car speeds are higher, potentially because building setbacks are too deep to inhibit them. The social connection capacities of the site are further lowered by a lack of a sidewalk on the eastern side, dominant blacktop parking lots (see Image 1A below), and low or disconnected surrounding housing densities in places (shaded green). The site has no street furniture or park space. Buildings were in poor condition and some were vacant (Images 1 C below).



Images 1: Cove Rd. (A and C on left) and Crystal Springs St. (B and D on right). Network relationships to street, walking, landscaping, and outdoor amenities diverge considerably.

By contrast, Crystal Springs Street has a number of amenities for pedestrians—street parking, vegetation strips, and benches (see Image 1B). Some restaurants also had fenced outdoor seating with high visual connections to passersby. Buildings have higher betweenness levels and are much more intensively occupied with diverse businesses to host ongoing commercial activities throughout the day and evening.

Spatial Network Categorical Discussion

A grounded theory study begins with and constantly returns to data as the foundation of theory building rather than hypothesis testing. As a result, the literature review and relationships to existing theory are not incorporated into the study until the later stages. The study here deviated from this norm in important ways. Previous theory and research were utilized to organize the initial study in such a way that complexity and

network theories and sciences were selected from the outset as the main research methodologies capable of incorporating development dynamics. Mutually dependent variables, nonlinear dynamics, as well as spatial and network structures were the justifications, however, for the grounded data material presented here they must be treated as acknowledged assumptions. There are few existing alternatives for a research exercise of this scope, but structuralism is but one means of epistemology, and it has its strengths and weaknesses for the theoretical modeling of contemporary urban development.

The weaving of network and development theory together is not original to this study either. The literature on urban development has been increasingly applying network tools and concepts for research and design. New computing power, modeling tools, and data sources drive much of the expanding quantitative efforts. As many developed world urban economies shift from mass manufacturing to services and innovation-driven workforces and businesses, there has also been considerable thought put into qualitative network concepts and theoretical relationships. To some extent, this has precipitated a rethinking about how urban space supports development, as well as how development as a concept ought to be defined (Feldman et al. 2016). By “re-grounding” much of this research and theory below with the findings of this study, the purposes of a more cohesive, integrated, and applicable network urban development theory can be advanced. Again, the iterative and recursive processes of complexity are inescapable for open, dynamic systems as well as their research. Constant change presupposes constant learning. In this phase, data and assessments from the Roanoke study are compared against data and assessments from other development studies.

With this in mind, mutually dependent variables and their feedbacks form the backbone of data gathering needs. In *The Nature of Economies*, Jane Jacobs (2000, p.37) defined economic *growth* as quantitative change, an overall increase of the amount of a resource of some kind. She defined *development* as incremental but significant qualitative change, a process of various forms of differentiation emerging from generalities which in turn become the new generalities spawning further differentiation. The development process as she describes it is dependent on *codevelopments* in the form of webs of cooperation, symbiosis, and interdependencies. Hence, you need networks bound through

codevelopment, or mutual signal and response feedbacks, to form a human habitat. The fundamental requirement for such a habitat was that it be a convenient site to meet and provide goods and services (p.55).

In addition to Jacob's elegant summary of the importance of networks for development, we now have mounting evidence from network and simulation science that many urban dynamics are codeveloping or *coevolving networks*. Coevolving networks add or subtract nodes and links according to some decision rule or local conditions. Havlin et al. (2012) report that the mathematic properties of more familiar *static networks*, such as transportation, power lines, sewer and other spatial infrastructure whose basic network structure are difficult to change, are fundamentally different from the mathematical properties of coevolving networks like social or commercial ties. Because static networks are so slow to change, they have an enduring and outside impact on framing, facilitating, and organizing faster network behaviors like social contacts and economic transactions. Basic scaling feedbacks make certain efficiency and congestion parameters spatially important for planning and design.

Such exchange sites are fundamental to the origins of cities, their expansion, as well as their revitalization. Ortman et al. (2015) applied mathematical metrics of modern city forms and compared them to pre-European contact cities in Central America. They characterize urban space as "social reactors" that to be functional require only "that a number of social encounters are realized over a specific geometry per unit time." They characterize the productivity of individuals within social networks as proportional to the number of interactions they have with others. Furthermore, as settlement sizes increase they find that urban movement space becomes more structured and differentiated to reduce transportation costs, which are the strongest constraint on energy flows such as food among social networks. With this model, the more technology facilitates transportation, the more land area a settlement can take up. In addition, the larger the social networks the more efficient and productive they are.

However, if these network benefits are not properly distributed then the equilibrium between the costs and benefits of dense social interaction can decline sharply with associated losses to productivity and efficiency due to "negative network social effects." Ortman et al. (2015) conclude that the evidence bears out the enduring historical

tension between the benefits of scale and the allocations of those benefits. Furthermore, the reinvestment of surpluses towards innovation that can increase baseline productivity over time is also necessary for long-term economic success. Some key points here are a) that social networks drive basic productivity by increasing network interaction densities (populations), if b) they are facilitated by physical networks, adequate resources, and transportation technologies. However, productivity languishes if investments in future productivity needs drop, or if the costs of participating in a network outweigh its benefits as returns on investment (ROI) become too concentrated (e.g., with elites). These points begin to hint at key development network system being a simultaneous, multi-level output of three interdependent and mutually reinforcing or disrupting network functions: a) spatial network *distribution* via transportation, b) social network *cooperation* enabled by population resource distributions via per capita income groupings, and c) research, innovation development, and investment for future needs via *planning* and *coordination* (see Table 2).

Table 2: Categorical Framework of Local Development Network Functions				
	Benefits	Costs	Social Metrics	Contemporary Forms
Spatial networks	Lower social network transaction costs & facilitate exchanges	Resources: building, maintenance, time, and/or energy	Social and cultural identification of status or stigma with place	Physical network map or graph
Social networks	Increase individual productivity by enhancing resource, information, and coordination signaling	Wages and (in)equity	Potential restrictions on freedom and identity due to behavioral norm policing (informal as well as legal and financial)	Firms, institutions, governments, and self-organizing local cultural and global informational signaling tools Place and cultural attachments
Development coordination networks	Form future physical and socio-economic networks. Expand knowledge and technical capacities. Envision plans and investments	Invest in Future or Performance decline due to obsolescence	Access to economic role modeling, business experience, and understanding of available public resources and private opportunities	Federal, state, regional, & local government links and restrictions; Activity links; Social links; Spatial links; Technology links; & Market links

Spatially, within an urban regional system as a whole, there must be a number of urban centers. As Hillier (2012) argues, urban fabric includes areas of low accessibility and areas of higher traffic and higher connectivity. He calls higher traffic areas *generative*, and these portions of urban networks can benefit businesses that need relatively higher flows of potential customers. This spatial sorting of urban space into neighborhood markets better organizes it for human contacts or *colocation* by both focusing and servicing neighborhood populations while also distributing such areas regionally so as to not overwhelm physical infrastructure with congestion or underwhelm an area with lack of services. Admittedly, this is not the urban pattern in many cities today where many communities have lost markets, services, and civic life to historical underinvestment or toxic planning efforts which can concentrate poverty and/or maximize land values and rents through zoning policies and public development projects (McGreevy and Wilson 2015).

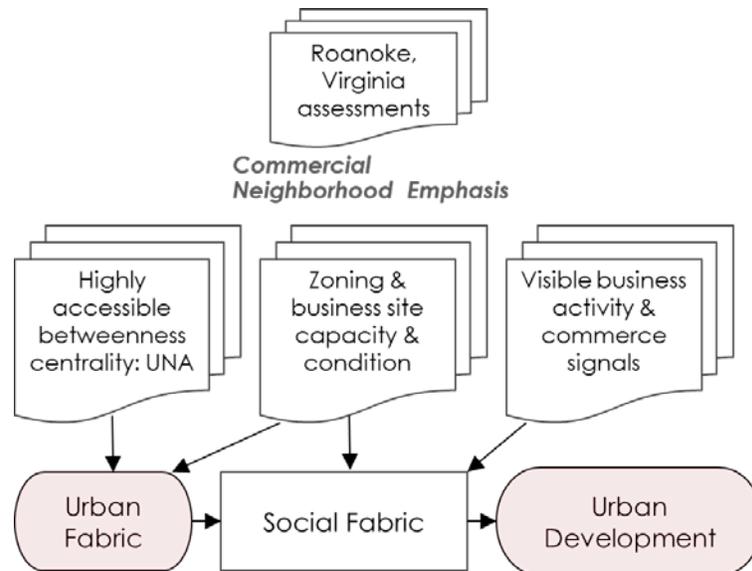
Essentially this *space syntax* process that Hillier (2012) describes is the formation of distributed neighborhood “urban village” commercial nodes. The distribution of both economic node size and distribution balances density throughout an urban fabric while maximizing connectivity (Salingaros 2010). If all activity happened in one single, overly dense place, congestion becomes a problem. By balancing greater and lesser densities while optimizing their proximity to one another, transportation time and energy costs strike a balance between link distance metrics like sprawl and congestion, as well as between costs for adding or subtracting new links to balance efficiency and redundancy needs.

These different network considerations also provide a multitude of connected, but individually oriented, points throughout an urban system to focus service delivery, cooperation, and coordination functions. Roanoke’s commercial functionality stems from the local and regional urban fabric. The urban colocation dynamics support the generation of social contact and commercial activities. These then are the physical substance of development as generic network processes (see Figure 1).

The enhancement of these properties relates to the scale and quality of business learning and transformation by scaling social efforts towards these new activities. Engagement in a variety of formal and informal coordination efforts works to both

facilitate meeting mutual goals and generate a sense of connectedness. Key areas can serve as hubs to connect people, enterprises, and facilities useful for remote, contract, or start-up scale businesses as well. Each network layer serves to knit the community together and coordinate information sharing.

Figure 1

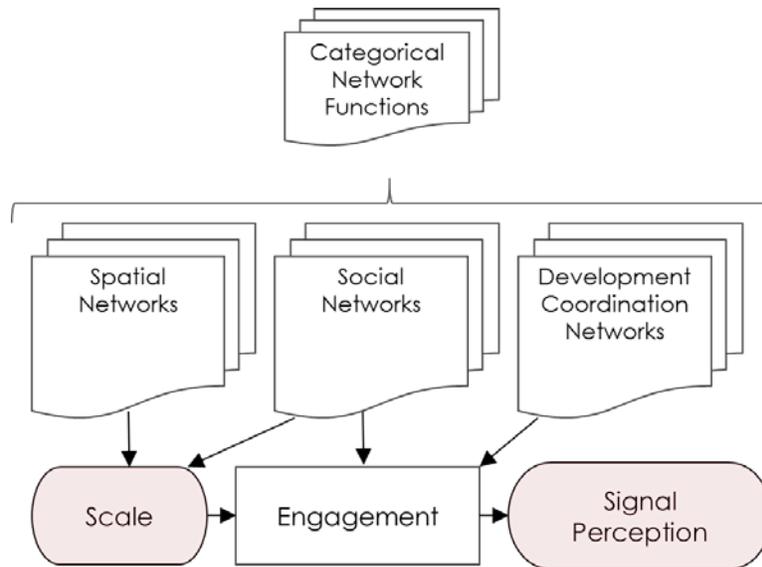


Whether a planning situation is supportive of adaptation and ongoing or expanding commercial success depends on both the scale of situational analysis as well as the specific economic contexts. For some successful Roanoke communities, there are currently few building vacancies, and most of the businesses have significant tenure and experience. The positive momentum of the neighborhood leaves owners free to focus on their individual businesses, save for episodic coordination efforts around event planning. This suggests perceptions of larger threats, opportunities, or other unifying purposes would be necessary to marshal greater engagement in development planning efforts. More local research would need to focus on what signals would constitute an incentive for coordinated transformation, and how decisions would be reached in response.

Development requires a certain population focused on exploring physical and market positions or business models to better engage with customers. The success of these efforts self-organizes and *engages* with the activity of commercial sites within cities

to in some way *scale* the levels of commerce. This localized focus on development network feedbacks like a neighborhoods' commercial and social activities points to important *scaling*, *perception*, and *engagement* dynamics as theoretical categories of development *network functions* for planning the complex system network dynamics and components (see Figure 2).

Figure 2



This network theoretical framework requires us to assess which areas are best for collecting the flow of people, or social network activity through a site and then evaluating the scale that each urban center is currently or potentially able to serve as a setting for development by hosting economic and social activity. In network terms, these development categorical functions can improve development outcomes by reducing transportation and energy costs while increasing social contact rates. With a stage set and an appropriate group of actors, the next three development aspects concern content or the cooperative scripting of development via signaling and boundaries. Functionally, a social network needs accurate signals drawn from its own nodes (individual agents), as well as other social, environmental, and financial networks that can be channeled into operating standards of behavior and mutual goal formation necessary for development.

In the simplest market terms, the information of greatest value for coordination enables customers and suppliers to identify one another, and then conduct their

exchanges with competitively low transaction costs. For those market exchanges which incorporate significant time lags between supplying a good or service and getting paid, the need for trust (either in the system or in individuals) is an issue. Nowak (2011), described research into cooperation dynamics using game theory models that point to mobility and location as important features for establishing a “fellowship of cooperators” among individuals. Areas that manage to build cooperative and trusting cultures tend to attract appropriately cooperative people. Alternatively, non-cooperative areas find it difficult to attract people voluntarily, so those areas and groups can dwindle and fade. This puts added strain on other nodes through the unbalancing effects of concentrating poverty and wealth, infrastructure and service decline, and cutting large populations off from important business opportunities, market signals, expertise, and investment. Over time these effects can either contribute to the collapse of an entire city as many Rustbelt cities demonstrated, or to the forming of new coalitions to plan and scale new investment initiatives (Safford 2009).

Summary

From a network standpoint, the local signaling, scale, and engaged connection can thus facilitate development interactions and coordination at all levels: places, people, and purpose:

1. Scaled networks can lower network exchange and operational costs,
2. Engaged social networks can increase individual productivity and coordination signaling, and
3. Development network coordination can enhance network renewal and the quantity/quality of information perception functions needed for adaptive speed.

Any of these ties and flows can dominate in a particular community. Any of these ties and flows can reinforce and coevolve with each other. The key principles are that they do not undermine the functional capacities of one another and that necessary signals saturate on some level sufficient to guide personal and collective behaviors towards prosperity.

While the contribution of a more grounded theory of network functions for a city like Roanoke facilitates analysis of urban development processes broadly, the ability to analyze the linkages between functions requires more study. We can look at patterns of

engagement, but we need to be able to see how those populations scale their activities. We also need to know how the processes of coordinated perception merge engagement, coordination, perception, in order to scale throughout a regional system. As with all complex adaptive systems, another limitation will always be the nonstop dance of coevolution. An open urban system, by definition, is changing. Networks theory makes it possible to better understand how those processes may be functioning well or not.

People have to be able to know important information to succeed commercially. It can come from the environment via personal observation, or second-hand via friends or media, but it will always have to be collected and shared (processed) to communicate the opportunity or risk status and contexts of the larger environment, social, and community system. Timely data is necessary for developing any urban system, but these data are not always easily acquired or systematized for network and economic analysis.

Developing, maintaining, and improving these information networks is fundamental to community and economic development. Recognizing the physical network character and function of relevant information flow via signals is important for cohesive urban development research, as it grounds other network characteristics on a common, coevolving, and complex framework. Future research to continue to better ground theories of underlying community and overlying market development behaviors and systems is thus better positioned to make further progress using network tools and theories.

References

- Appleyard, D. (1981). Three streets in San Francisco. In *Livable streets*. Berkeley, CA: University of California Press, pp. 15-28.
- Beinhocker, E. D. (2006). *The origin of wealth: Evolution, complexity, and the radical remaking of economics*. Boston, Mass: Harvard Business School Press.
- Bettencourt, L. M. A. (2013). The origins of scaling in cities. *Science (New York, N.Y.)*, 340(6139), 1438-1441.
- Betz, M. R., Partridge, M. D., Kraybill, D. S., & Lobao, L. (2012). Why do localities provide economic development incentives?: Geographic competition, political constituencies, and government capacity. *Growth and Change*, 43(3), 361-391.
- Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. London: Sage Publications.
- Feldman, M., Hadjimichael, T., Lanahan, L., & Kemeny, T. (2016). The logic of economic development: A definition and model for investment. *Environment and Planning C: Government and Policy*, 34(1), 5-21.
doi:10.1177/0263774X15614653
- Fullilove, M. T. (2004). *Root shock: How tearing up city neighborhoods hurts America, and what we can do about it* (1st ed.). New York: One World/Ballantine Books: 71-100.
- Havlin, S., Kurths, J., Portugali, J., Solomon, S., Kenett, D. Y., Ben-Jacob, E., Bunde, A., Cohen, R., Hermann, H., Kantelhardt, J. W., Kertész, J., & Kirkpatrick, S. (2012). Challenges in network science: Applications to infrastructures, climate, social systems and economics. *The European Physical Journal Special Topics*, 214(1), 273-293.
- Heacock, E., & Hollander, J. (2011). A grounded theory approach to development suitability analysis. *Landscape and Urban Planning*, 100(1), 109-116.
doi:10.1016/j.landurbplan.2010.12.001
- Hillier, B. (2012). The Genetic Code for Cities: Is it Simpler than We Think? In J. Portugali, Meyer, H., Stolk, E., and Tan, E. (eds.) *Complexity Theories of Cities Have Come of Age: An overview with implications to urban planning and design*. New York: Springer: 24-47.
- Holcombe, R. G. (2013). *Producing prosperity: An inquiry into the operation of the market process*. New York; London: Routledge.
- Holland, J. H. (2012). *Signals and boundaries: Building blocks for complex adaptive systems*. Cambridge, Mass: MIT Press.
- Jacobs, J. (2000). *The nature of economies*. New York: Modern Library.
- Larson, R. C., & Odoni, A. R. (1981). Applications of Network Models. In *Urban operations research*. Belmont, Mass: Dynamic Ideas.
- Low, S., Taplin, D., & Scheld, S. (2005). *Rethinking Urban Parks: Public Space and Cultural Diversity*.
- McGreevy, M & Wilson, L. (2016). The civic and neighbourhood commons as complex adaptive systems: The economic vitality of the centre. *Planning Theory*.
doi:10.1177/1473095216631587
- Michelson, W. (1970). Determinism by the urban environment. In *Man and his urban environment: A sociological approach*. Reading, MA: Addison-Wesley: 168-190.

- Misra, S., & Stokols, D. (2012). A typology of people–environment relationships in the digital age. *Technology in Society*, 34(4), 311-325.
doi:10.1016/j.techsoc.2012.10.003
- Nowak, M. A., with Highfield, R. (2011). *SuperCooperators: Altruism, evolution, and why we need each other to succeed*. New York: Free Press.
- Ortman, S. G., Cabaniss, A. H. F., Sturm, J. O., & Bettencourt, L. M. A. (2015). Settlement scaling and increasing returns in an ancient society. *Science Advances*, 1(1), e1400066-e1400066. doi:10.1126/sciadv.1400066
- Pentland, A. (2008). *Honest signals: How they shape our world*. Cambridge, Mass: MIT Press.
- Piketty, T., & Goldhammer, A (trans). (2014). *Capital in the twenty-first century*. Cambridge Massachusetts: The Belknap Press of Harvard University Press.
- Raparathi, K. (2014). Assessing smart-growth strategies in Indian cities: Grounded theory approach to planning practice. *Journal of Urban Planning and Development*, 5014031.
- Safford, S. (2009). *Why the garden club couldn't save Youngstown: The transformation of the rust belt*. Cambridge, Mass: Harvard University Press.
- Salingaros, N. A. (2010). *Twelve lectures on architecture: Algorithmic sustainable design: Notes from a series of 12 lectures applying cutting-edge mathematical techniques to architectural and urban design*. Solingen: Umbau-Verlag.
- Sampson, R. J. (2012). *Great American city: Chicago and the enduring neighborhood effect*. Chicago: The University of Chicago Press.
- Sevtsuk, A., Mekonnen, M. (2012). Urban Network Analysis Toolbox, *International Journal of Geomatics and Spatial Analysis*, vol. 22, no. 2, 287–305.
- Silver, C. (1987). Urban planning in the new south. *Journal of Planning Literature*, 2(4), 371-383. doi:10.1177/088541228700200401
- Stokols, D. (1981). The environmental context of behavior and well-being. In D. Perlman & C. Cozby (Eds.), *Social psychology*. NY: Holt, Rinehart, and Winston: 442-472.
- Wicker, A.W. (1979). Introduction. In *Behavior settings: An introduction to ecological psychology*. Monterey, CA: Brooks/Cole: 1-25.

Chapter 4: Grounding an Urban Development Theory of Network Forms

Introduction

Developing neighborhood buildings, paths, aesthetics, and other physical qualities can enhance social and financial values and activities within the community. Such economic network relations together channel much of urban life by focusing and scaling economic activities (see previous chapter). Location property values, zoning, retail, restaurants, services, as well as customer, employee, and residential populations, mutually influence development in good, bad, and complex ways. Understanding these networked mutually dependent forces as amplifying (positive) or regulating (negative) feedbacks makes it possible to discern ongoing and diverging development patterns (i.e., exponential increase/decrease, concentration/diffusion, and stability/instability dynamics). By contrast, linear relationships can be statistically engineered and therefore are more easily understood and managed. Unplannable chaotic systems have no discernable relationships between variables. The complexity of development factors like neighborhood to regional scaling, business adaptation, market perception, and other systemic relationships are defined instead by linked nonlinear feedback operations, and these dynamics remain poorly studied and applied for organizing the networked forms of development planning.

Urban development planning needs stronger theory relating to system connections and feedback loops. Complex coevolving interactions occur across and between different forms of urban networks. Physical networks, social networks, financial networks, and knowledge networks have both specific and shared dynamics with implications for development. Miller (2015, p. 231-232) observes that “Anytime we interconnect systems, we build in feedback loops. Some types of feedback result in stabilizing forces, calming the system as a whole. Alas, other types of feedback destabilize systems, and even with careful thinking and design, it is easy to build systems with unintentional –and unfortunate feedback loops.” By improving understanding of development feedbacks and their network contexts, development systems can be better understood. For these reasons, planning urban development systems are in large measure fundamentally about structuring the feedback dynamics as operationalized by and through network forms and

flows. However, for applied urban planning, the theories, models, and technologies suitable for coevolving feedbacks will only be as strong as the real-world network observations on which they are based. In emergent systems, small initial distinctions can fundamentally alter outcomes.

Study Purpose and Research Questions

In order to better define and ground these coevolving network relations and elements, this grounded study examines three adjacent commercial neighborhoods, or *urban villages*, in the City of Roanoke, Virginia. Semi-structured interviews of sixteen individuals active in development activities within one of the three communities were conducted to better understand the interdependent role of different networks—such as social, physical, and regional commercial interactions—to individual’s development decisions and perspectives. Following the discussion of the findings from these personal narratives, a categorical framework is introduced to ground the qualitative interview data, physical network data, and subsequently multi-disciplinary development literature towards stronger development theory.

Specifically, complex adaptive systems of urban development are poorly understood between multiple co-evolving networks, including local to regional, social to physical, and information perception to individual behavioral strategy levels among others. By examining the development trajectories of these neighboring communities to see what they can teach about how these network exchanges and mutual evolution occur, important elements can emerge for a theoretical network framework for urban development planning.

This study presents a series of research topics to explore *what development information dynamics occur at the study sites*. The interview questions focused on examining:

- A. What economic patterns are driving development in certain commercial neighborhoods of the City of Roanoke, Virginia?
- B. What experiences and other information guided primary business development and location decisions in these neighborhoods?
- C. What social network structures and activities in these neighborhoods are important?

- D. What site advantages, disadvantages, and investments define urban design development in these neighborhoods?
- E. What locational factors are influencing further development planning?
- F. What are the perceived development trajectories from neighborhood to regional scales?

By asking open-ended questions of interviewees, the study sought to discern important network coevolving processes, patterns, and feedback interrelationships. A substantial number of urban planning decisions are implicated by these considerations, and better understanding their development implications can contribute to more effective planning of urban systems overall.

Grandin Village, West End Village, and 11th Street Corridor

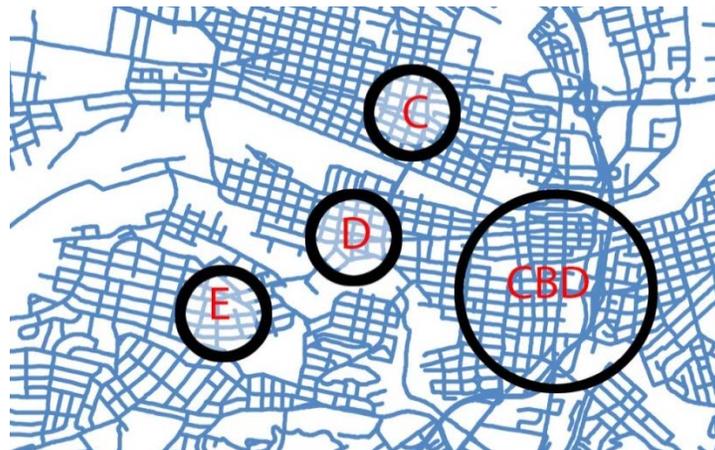
Although neighbors (See Map 2), the development histories of these commercial neighborhoods incorporate some of the peaks and valleys of the City of Roanoke's development history. As Roanoke attempts to heal and recover from periods of blight, segregation, and displacement, it must chart distinct but mutually supportive courses to restore commercial activity and other urban services to struggling communities while also continuing to support stronger areas towards regional success and stability.



Map 1A: Grandin Village (top left). 1B: 11th Street Corridor (top right). 1C. West End Village (bottom). Scales 1:4000. Gray indicates surfaces such as parking lots and railroads. Purple is vacant/open commercially zoned space.

The 11th Street Corridor is the last remaining commercial neighborhood portion of what one resident termed Roanoke’s “Black Wall Street.” After decades of redlining, eminent domain displacements, and urban renewal developments (heavy on large parking lots and car-oriented chain businesses), little commercial space or activity survives to support a largely impoverished surrounding population. The urban form features numerous vacant or boarded up buildings, and accessing commercial services like restaurants or food stores requires a bus or taxi trip for those who cannot afford cars.

Map 2: Spatial positions of 11th St. Corridor (C), West End Village (D), Grandin Village (E), and Downtown (CBD) of the City of Roanoke, Virginia. Railroads mostly separate C from D and Downtown areas, and the Roanoke River mostly separates E from D.



The newly rebranded “West End Village” incorporates some of the most historic and formerly grand housing in the City. Unfortunately, decades of disinvestment, criminal activity, and poverty took their toll. In just a few short years, however, considerable multi-stakeholder housing, banking, and street investments by the community, the city, and other partners have seen housing values increased dramatically, and new businesses are slated to soon follow to reactivate long vacant commercial spaces (Olson et al. 2013). As this community shifts, it remains to be seen whether these investments will be enough to support ongoing reinvestment processes longer term, and whether, if successful, it will then result in gentrification displacement that can deny the benefits of investments to struggling residents.

Grandin Village is Roanoke's premier urban village success story. While it too struggled with under-investment for years, the latent attractions of quality buildings, business leadership, and densities sufficient to draw and keep the interest of customers led to a contemporary blooming over the past 20 years or so. Its mix of retail, entertainment, restaurants, and service enterprises draws in customers on foot, bike, and car from the neighborhood and affluent communities throughout Southwest Virginia. Despite these successes, many of its less-established and a few of its more-established businesses struggle to find the customer, financial, and business partner access to support ongoing development.

To establish these urban histories and potential future trajectories within the conceptual formats of networks and complex adaptive systems, a more precise, mutually compatible, and functional set of standards is introduced below. Viewing these systems of networks as they generate urban development patterns is important for grounding individual narratives into a more general framework supportive of cooperative actions like planning and further research actions like modeling. As Neal (2013, p. 5) argues, networks are both theory and methodology—they are a way of both perceiving and measuring the world. Therefore, despite the mathematical structure of network graphs, interpretations to perceive and define network dynamics can be more qualitative. The key research goal is a theoretical and methodological approach both consistent and viable for interdisciplinary, urban complexity research.

Site Networks and Experimental Targeting Feedback Dynamics

Interviews at the three commercial neighborhood sites included two each at the 11th Street Corridor and the West End Village and one interview with a City official regarding West End projects. Both locations had 5 or fewer businesses in their core commercial zone, and many of those businesses, such as catering and equipment rental, do not have conventional storefronts or businesses which support community street life and shared commerce. There were 11 interviews from the more extensive businesses of Grandin Village for a total interview pool of 16.

Grandin Village has the kind of thriving commercial activity that would be the envy of many neighborhoods. Despite its many advantages, the stories of its successful

businesses include consistent locational experimentation, substitution, and plenty of doubts—in the past and for the future. Since many of the longest tenured businesses began in Grandin in the 1990s, many neighboring businesses have come and gone. The drugstore is gone. The hardware store is gone. Restaurants have closed. Restaurants have opened. A newer business type, a co-working hub, now occupies the former drugstore. The building which is now a used bookstore has, for most of the last century, housed pharmacies, beauty parlors, bars, and other shops, as well as employees and owners in the apartments above. As network tools, these buildings have continued their functions as nodes to this day, though the specific economic flows of those nodes have often changed.

For any business to exist the founders have to have an initial vision of its business plan—a mental model—of how it will access or create a customer base to profitably support operations using available and affordable resources. There must be a convergence of customer sales, rents, supply chains, wages, other expenses such that financial feedbacks, the revenues, can sustain operations. Business development hinges on the experimental performance of the information and motivation underlying these planning models. Community development occurs around the recursive creation, scaling, and replacement of these models as revenue streams (and perhaps management’s motivations) ebb and flow over time. Perhaps one of the most important considerations for urban sites that host these complex networked systems of business modeling and remodeling is the ongoing pattern of customer-adaptation.

There were various reasons given by the 11 owners or operators of Grandin businesses as to why they chose their particular business model as a vocation. Some had a particular passion for their products and interactions with the people that bought them. Some needed an income and had enough interest and experience to want to give running another store or restaurant a shot. Many of Grandin’s businesses began in other locations around the city and relocated to Grandin intentionally to better target the business’s core customers, shared community character, or the pool of regional customers the village attracts through its diverse attractions.

The fact that so many interviewees either gained significant experience or originally opened their businesses in other areas in the city suggests two important feedbacks which together might be called “experimental targeting.” An initial business

model, once established, is an exploration of a customer base. Over time, as the assumptions of a model are tested and business strategy is adapted, a business may target available sites to better target their customers as an important form of adaptation. Over yet more time, the agglomeration of successful businesses can mutually enhance the community's success—due to attracting a particular shared or complementary customer base or generating activities that diversify and sustain-by-adapting with new customers. These customer scaling feedback properties are coevolving. Diversity can generate more customer volume if complementary, and volume can generate and support diversity if complexity is maintained.

Neighborhood network feedback conditions matter for constituent business development. Customer patronage can potentially destroy diversity under certain gentrifying feedback conditions due to popularity driving up rents, and diversity can reduce customer traffic volumes due to stigma or hostility under certain segregating feedback conditions. Based on interviews, one of Grandin Village's great site attractions for businesses is its complementary commerce which makes it a regional, and occasionally national, destination. One point of future research this raises is whether changing levels of business diversity or complementarity would be better for Grandin Village's businesses collectively over time. Will Grandin prosper best by attracting completely new customers, or by providing a greater range of offerings to its core existing customers so that they come more often, stay longer, and spend more when they do? It is in this sense that "experimental targeting" is complex. The answer to these questions will depend on local, regional, and global conditions as different conditions favor different strategies.

For this reason, a core issue for development is not just the active and conscious application of network feedback tools to guide planning relative to diversity and scaling, but the more critical issues related to business modeling itself—situational information, business experience and knowledge, and personal motivation. To what extent can a site support information interaction dynamics to familiarize workers with business methods, practices, and other opportunities? How can a site's activities encourage innovative business strategies and adjustments? Under what conditions is it more critical that businesses do so? To what extent are experienced business operators able to keep and

discover new customers? These kinds of questions are extremely difficult to study without a longitudinal study of change.

Grandin's history holds some valuable clues to these processes. At first glance, most of Grandin's business models are familiar. Movies theaters, groceries, furniture, clothing, bookstores, and restaurants have been urban standards. This belies the amount of adaptation that went into many of these businesses' modeling, planning, and targeting over the years, however. Businesses have to change with the times, particularly if they are competing for present and future customers with Amazon, Netflix, Ikea, or Wal-Mart.

Interviewees related what a loss it was when Grandin Theatre closed for many years, and to survive after re-opening it must now find innovative civic programming as well as movies to coexist with larger, newer area cinemas. Grandin has two groceries, and one of them is an organic coop that developed different sites, products, and overall business models over decades. As it looks to its future the coop continues to weigh its products, sites, and investments carefully. Over decades, the high-end furniture store has had to deal with local and regional furniture warehouses and shifts in personal and generational differences in taste, lifestyle, household establishment, and affordability. Knowing their customers and vendors very well has been critical. They have had to weather economic downturns aplenty as well. Assuming success moving forward, grooming a new generation to take over the business is an important planning consideration. Who will have the vision and the motivation? Clothing constantly changes with fashions, and used bookstores have all but disappeared in this region under the pressure of internet sales and e-readers. Some of Grandin's newer restaurants have closed after just a year or two. A restaurant that has just moved to Grandin has worked for years to find an appropriate location, ambiance, and leasing arrangement to keep its business vision vital. This new Grandin location is another experiment in that journey.

Before turning to extensive redevelopment efforts in the West End Village, the 11th Street Corridor is discussed in the context of nascent development initiatives and ongoing signals of socioeconomic struggle. If Grandin Village is harvesting the commercial benefits of many years of effort, practice, and investment, 11th Street is still trying to prepare some soil for appropriate seeds of re-development. In order to do so, the physical legacy of streets, buildings, and active enterprises point to more inhibiting social

contexts and public perception feedbacks—many of them legacies of Roanoke’s more divisive development and ethnic history—that have atrophied development network activity in the area for generations.

Network Dynamics of Depreciating Decline and Appreciating Recovery

As in many cities, federal urban renewal policies as applied in Roanoke led to massive losses in African American housing, commercial, and civic structures and institutions, as well as associated social and urban fabrics. Previous to these dislocations and spatial erasures, federal housing redlining practices denied loans in ethnically diverse areas which effectively created disinvestment feedbacks that continue to influence property values to the present day. Fullilove’s (2004, p. 93) study of the destructive consequences of urban renewal in several US cities included research on areas of Roanoke adjacent to downtown like 11th Street. She writes: “The area of the invisible inner city overlaps with the inner section of African American settlement, the second ghetto that has been pushed to the northwest from its origins in the center of town. By 2003, Roanoke was noted to be one of the most segregated cities in America, and many of the African Americans in Roanoke lived in the redlined zone....” During interviews, this development legacy was considered a present-tense challenge, with government services described as either absent or disrespectfully hostile.

Various site disadvantages were described in two interviews in the 11th Street Corridor. In the context of such a struggling community, these disadvantages amount to the perceived development challenges undermining important commercial activities. After long fallow years, the 11th Street Corridor may be getting critical early investments in leadership, infrastructure, and imagination. However, the needs—in building, streetscape, business planning, and human terms—are very great. As feedbacks, financial flows into a community, whether as daily sales or larger building, business, or street investments are necessary to even maintain development levels. In this basic commercial activity is a regulating (negative) feedback for maintenance, repair, and living expenses for enterprises. Relatively greater investments may appreciate the value of assets and commercial activities, and neglect, stigma, or damage to assets may depreciate their value through an ongoing declining feedback loop. One of the points made by multiple

interviewees was their internalization of the well-being of where they lived and worked with their own well-being. On 11th Street, that contributes to a lot of hopelessness.

When the local 11th Street barber talks about development planning in his neighborhood, you hear a network language. As an African American barber, he is fully aware of their historic role as pillars of the community, responsible for providing a comfortable home and forum for that community so it can serve as a community “information conduit.” He is also active with his brother in running a rapid reaction community development nonprofit next door to bring “connectivity.” Their engagement efforts include collaborations with other groups and community champions to teach, mentor, dialogue and stay “focused on this community spending money to build a stronger network here.” His development perspective for the Corridor is activating and improving “dead space”—the streets, buildings, foot traffic, employment, poverty, neighborhood reputation, even “old thinking” (perceptions), with more active signals and models. Central to this is an attack on poverty with employment outreach efforts: “Kids are learning to be drug dealers. It’s the only thing they see people do to make money.”

For prospective development agents, the perception of strategies or circumstances likely to stabilize or appreciate the value of their investments—in time, money, skill, or effort—are fundamental to the possibility to scale those contributions towards ongoing success. For this reason, data categories related to mental model characteristics such as stigma, control/policing, and the visual cues like the condition of infrastructure or employment activity role modeling speak so powerfully in the context of development at this site. For interviewees, shifting perceptions are key to development strategies. However, they must somehow shift community signs and narratives at physical, economic, and psychological levels simultaneously or further depreciation and neglect functions as a counter-narrative to discourage “hope”—a belief in appreciating conditions. If that were not challenging enough to scale, many of the residents of the 11th Street neighborhood show symptoms of trauma from the conditions and consequences of intergenerational poverty and social dissolution.

Another local leader serves as the assistant director of a nonprofit, Roanoke Role Models, and the site operator of the organization’s 11th Street Hope Center. The nonprofit began several months ago at a building in the Corridor in response to an earlier (August

2015) school supply donation effort. Not many impoverished families had access to cars, so the site had to be within walking distance, and the children had to be physically present to get a book bag full of supplies. They had 165 kids show up. But they only had 100 bags. It would be discovered that about 600 school age children in Roanoke were homeless. In order to meet the needs of area homeless the nonprofit needed a more permanent site, and after praying about this she felt led back to a building across the street of the original book bag event. Now they provide afterschool homework support for kids, and adult resume help on computers bought with borrowed money. In addition to a food pantry sufficient to provide hungry individuals a hot meal, they have giveaways and thrift “sales” of donated clothes. Students can “buy” clothes with board game money they are given.

Before the students arrive in the afternoon, the Hope Center provides public access to people in the community for whatever they might need. She sees this role as listening to people to better understand what they need and what they are going through. Her development model language is rooted in more emotional terms—that other social network language of limbic connection and non-judgmental social status—as a tool or barrier for development services:

Love. Respect. Treating people with some kind of decency. A lot of organizations that offer services come to a place where they treat people badly. Then people shy away from you. The main problem is love. We’ve forgotten how to love. You see their heart and you know that they are hurting: Can you love me in my drunken state? I can love them to their next place. That’s what we are right here. We are the community center—a point of contact.

The spatial and social influences on social dignity and emotional coping strategies represent another layer of social signaling that deviates sharply from the dynamics of Grandin. The development task of engaging and connecting with people in struggling areas can mean that the bureaucratic or business models of service access and delivery are poorly designed for traumatized populations. Information processing requirements for planning or longer-term mental model construction and strategy formulation are extremely inhibited in individuals under stress:

When a person is in a persistent low-level fear state, the primary areas of the brain that are processing information develop differently. Frightened people are dominated by subcortical and limbic activity.... As a result, they are desperate for immediate relief, and delayed gratification is difficult, if not impossible (van der Kolk 2009, p.458).

Compound those social dynamics with the very visible conditions that the community lacks institutions and services it needs to thrive, and the depreciating feedbacks in this neighborhood seem “hopeless.” In the Hope Center leader’s words, “The biggest thing that’s over here is the hopelessness. We are in a rut, cycling around.”

As the development actors of the 11th Street Corridor work to forge connections and access resources to generate reinvestment and planning activities in their community to reverse the cycle of hopelessness, evidence that it is possible is near at hand. The commercial corridor within the West End Village community continues to have much in common with neighboring 11th Street’s struggles about 12 blocks northeast. Many of its best commercial buildings sit empty, and access to food and financial services have only arrived in recent years (see below). However, after millions of dollars in investment, the development future of the West End has many appreciating assets to feedback upon.

The West End neighborhood had hit a bottom by 1979. With its decline, many became concerned with unsupervised children, so two area churches and a neighborhood organization formed the West End Center for Youth to provide a structured environment. It was held in a house for years, before moving to a collection of buildings at the key community commercial street intersection in the mid-nineties. According to its director, the West End Center has over 35 years of experience with tutoring and other academic support. To meet changing needs, it has evolved to provide new development skills needed to succeed as adults such as social skills as well as science, technical, and math skills that have the best economic futures. From the beginning, it struggled with the rest of the community for resources, but as it was able to join with other groups in the region it was able to raise its profile and capacities.

In 2009, a regional financial cooperative, Freedom First Credit Union (FF), had been studying its service population to make sure it was offering the right financial products. That population was 66 percent low to moderate income. FF is also a part of the

U.S. Treasury Department’s Community Development Financial Institution (CDFI) Program through which federal dollars and training are used to support the provision of not-for-profit loans, funds, and technical services to underserved markets and populations. As part of this mission, FF pursued a federal grant with an interest in establishing banking facility in the West End, a conspicuous local “financial desert” targeted by the City for community development efforts. FF was awarded the \$850,000 federal grant, and, after an ongoing planning and collaboration process, they opened a unique banking, farmer’s market, and food preparation facility on one of the West End Center’s lots.

According to a FF official active in the process, because of their CDFI status and the conditions of the community development block grant, FF was not able to acquire capital through their investment so they needed a partner for their new building. The credit union had worked with the West End Center on employee volunteer days in past years and had a comfortable working relationship. The organization also had good program metrics. The idea of creating an income producing investment for the Center’s children services eventually became a full spatial development program plan “to create a central location where people could congregate.” In addition to FF Credit Union facilities leased from the West End Center, the building has a resource room for community meetings, a covered outdoor space for the local farmer’s market to keep bringing people to the neighborhood, and a large adaptable kitchen space where individuals wishing to create food businesses can access the required certified facilities they need in a “community kitchen” or food “maker space.” By partnering with a local community food nonprofit with this latter program, this facility attempts to create a central oasis in what had been a food and finance desert, an area where access to these vital services was restricted, difficult, or locally nonexistent.

The credit union official responsible for community development reported this was part of larger systemic effort to stabilize local households and the neighborhood as a whole, but working to provide healthy food and nutrition information, health levels can improve. By improving decisions relating to the family food budget—a critical household expense—families can save money and lower health costs, and begin to save assets, which they can manage at the credit union. They have workforce development loan

products available for starting businesses or getting training and education. There are car loans for financing transportation needs, and housing loans to transition residents away from renting. Referencing an architectural study in the area (see ELA 2013 and below), he noted a need for a grocery store, gas station, pharmacy, or doctor's office. A new grocery store will soon open across the street with a loan from the credit union. In his words, "We are able to make these local decisions here. We understand our market. We can also identify those weaknesses and make it a better place."

The West End Center's director and board saw the partnership with the credit union and food group as an extension of their work by supporting families. She said that when one of her client's grandmother heard about the credit union coming the first thing she said was "There will be jobs." Part of the Center's work was to bring in role models for their youth to aspire to. The family structure is largely one of single mothers locked into low-paying work who are able to make ends meet through government benefits. Giving young people exposure to alternatives can provide a lifeline to something better. In her words, "Most people grow towards the existing course." As a development feedback, the exposure to needed services can function to diversify development "courses" and successful role models for area children playing next door.

For both West End interviewees, the growing community investment had helped to change the broader external narrative of blight, crime, and that this was a bad place. More importantly for the West End Center director, "Everything says to the community: You're worth it, we trust you." This instills pride, a desire to take care of their community and one another, and to take advantage of new opportunities.

In 2009, a City of Roanoke task force selected the West End to be the fourth defined neighborhood targeted for 3 years of public development dollars matched to private investment. According to an interviewed city official, federal Housing and Urban Development funds were applied towards:

- 27 new homeowner projects by Habitat for Humanity,
- 60 limited housing rehabilitations (\$15,000 or less),
- 18 residential façade improvements,
- 4 major housing rehabilitations (from \$15,000-75,000; though 1 exceeded that),
- \$453,000 into the West End Center – Freedom First project,

- \$1,300,000 in street improvements to landscaping, curbs, gutters, and pipe improvements,
- 3 pending commercial façade improvements (up to \$25,000 with potential to double that through Enterprise Zone funds from the City Department of Economic Development).

Additional programs included a successful 2011 community and bike policing effort to stamp out rampant criminal activities in the area and increase perceptions of public safety, and an unsuccessful rental housing interior rehabilitation program that did not get much owner support. Since 2009, the average housing value of West End residences has increased by tens of thousands of dollars, by as much as \$50,000.

In 2013, the Virginia Society of the American Institute of Architect’s Emerging Leaders in Architecture (ELA) program selected the neighborhood’s commercial corridor as its year-long capstone design project, *West End Village: A Campaign to Change Perceptions* (ELA 2013). This project set as its overt goal the shifting of perceptions through urban design transformations in street furniture, sidewalk lighting, and landscaping, as well as developing plans for needed urban services. These longer-term business goals included a laundromat, grocery store, restaurants, and retail shops. Recognizing that since a majority of community residents did not have access to their own car, these necessities were essential to community function as well as for activating the public economic spaces and inviting the rest of the city to come, shop, share, and invest. Additional design plans included upgraded activating dead, paved space for walkers and bikers, upgraded bus stops, orienting signage and branding designs, and a truly innovative “Info Node” design to compensate for a lack of local access to transportation and the internet. Info Nodes would be a phone booth scale weatherproofed system to communicate development programs and facilitate the mailing of applications for various types of personal, homeowner, and small business aids, incentives, and grants for stabilizing local finances (ELA, 2013, p. 72-75). The focus on enhancing perceptions and engagement by utilizing urban design could not be more overt than this consultation effort, nor could the importance of multiple layers of development network node design. The street improvements are ongoing. The Info Nodes are still just concepts. And the West End Center is still surrounded by vacant buildings. But the loan applications to the credit union to fill commercial buildings are flowing freely. Is this early successful

evidence of a network-driven development model that directly addresses urban complexity, interlocking structural scales, and feedback processes?

Another recent case study of the West End suggests it is. Using a “community narratives” methodology towards understanding “the complexity of ‘whole communities’ in a holistic way,” Olson et al. (2015, p. 43) studied the impact of the efforts of the local chapter of Habitat for Humanity and the other development initiatives referenced above. Their 20 respondents reported definite themes of community development during the post-2008 initiatives that had begun to reverse decades of disinvestment and deterioration. Their development logic model for the West End community shows the systemic feedbacks whereby A) collaborative partnerships target an “edge” community between two stronger communities ripe for investment B) property and public safety improvements enhance habitats, stabilize homeownership, and incentivize improvements to neighboring properties in a cascade effect, which C) improves social cohesion, economic commercial investment activity, and civic engagement, all of which D) enhance the neighborhood quality of life supportive of further (scaling of) engagement, commerce, more safety from passive street surveillance, and overall cohesion (p. 48). They write “Reflected in many stakeholder interviews and consistent with the [Neighborhood Revitalization] initiative mission, increased economic resources, landscape improvements, and increased social interactions led to a greater sense of connection to the neighborhood” (p. 49). Habitat for Humanity also discovered the added efficiency improvements from spatial concentration as supervisors could cover multiple sites simultaneously, move people and resources more easily, scale educational programs on finance and home maintenance, and benefit more from the revitalization efforts of higher-end housing developers active in the same area (p.50). Again, a pattern is evident of urban network and development feedbacks generating enhancement and community stabilization where there had been feedbacks of physical blight, social disintegration, and financial depreciation.

Feedback Categorical Summary

The feedback dynamics at work in urban complexity are themes which, if adequately theoretically identified, can guide network decisions to utilize systemic

dynamics towards enhancing local and regional development planning. As has been described, physically perceptible signals of social activity, investment signals, as well as welcoming or warning marks can influence the commercial patterns and development characteristics at each site.

The process of organizing disparate data into a cohesive theoretical framework or system is one that can never be static due to inherent qualities of complex adaptive systems and local urban change. The following theoretical structures must be reassessed and reinterpreted *systematically* on an ongoing basis. This is true for grounded theory research, modeling theory research, and development theory research which must all be sensitive to shifts in data, interpretation, and pattern evolution. In order to successfully study and utilize complexity functions for urban development, the research and planning processes must incorporate adaptive feedbacks as well if it is to keep up with ongoing change. As will become more apparent, this means that planning research necessarily coevolves in relationship with its topics of inquiry.

In order to keep a manageable research focus, the categorical organization of observable data for consisted of qualitative designations of observable development network *change* for the Roanoke commercial neighborhood sites, specifically Grandin Village, West End Village, and 11th Street Corridor. Because structured networks consist of *nodes*, *links*, and *flows*, different elements of the physical sites can be categorically coded to indicate network development conditions (or trajectories) of local dynamics. The overall network conditions for these sites were assessed according to the fundamental changes in network access links to surrounding buildings, changes in buildings (nodes) and the environment that would affect internal foot traffic patterns (flows), new activity capacities (nodes) that could link more people to the site, the levels of active business nodes, the vacant buildings and lots or latent nodes, as well as any transitional or experimental commercial spaces like open air markets, food or retail stands, business incubators, maker-spaces, or co-working sites that would indicate high “link-seeking” experimental targeting of new customers activity.

As Table 1 indicates, these network qualities were assessed as to whether the commercial center appeared to be adding, stabilizing, or losing nodes and/or links, as well as whether unused capacities were dormant (vacant) or being repurposed by

experimenting with new connecting possibilities through businesses or activities. In terms of development opportunities, the adding or subtracting of nodes and links over time is often a key signal of resource flow trends. Network maintenance costs are justified by usage, and their development must somehow internalize these costs or be subsidized (Jacobs 2000, p. 111). These addition and subtraction pressures in turn help to inform which development opportunities are actively shifting, where they are, and the economic and social functions that are supported, emerging, or being lost over time. The most obvious observable data for urban commerce is which coevolving networks of businesses and customers currently use a site. Development opportunities, however, references change into the future not just current activity, so valuable information would also signal what latent capacity for customer goods and services could potentially be met by new or expanding network conditions at a site.

Table 1: Site Network Conditions and Trajectories				
<i>Network Component</i>	<i>Descriptive Indicator</i>	<i>Trends</i>		
		<i>Grandin Village</i>	<i>West End Village</i>	<i>11th Street Corridor</i>
Links to surroundings (external)	Center accessibility	Appreciating Feedbacks	Stabilizing Feedbacks	Depreciating Feedbacks
Links to passersby (internal)	Building & environmental attractiveness	Stabilizing Feedbacks	Mixed	Depreciating Feedbacks
Links for activities	Diversity of social functions	Stabilizing Feedbacks	Stabilizing Feedbacks	Depreciating Feedbacks
Active nodes	Building occupancy	Stabilizing Feedbacks	Stabilizing Feedbacks	Depreciating Feedbacks
Latent nodes	Vacant buildings or lots	Low	High	High
Transitional nodes & links	Market-customer seeking experiments	Appreciating Feedbacks	Appreciating Feedbacks	Stabilizing Feedbacks

Where **appreciating** means increased property or activity values, **stabilizing** indicates minimal recent change, **depreciating** indicates building vacancy or worsening site conditions, **mixed** indicates both building or site condition decline and development, and **high/low** means the general ratio of active-to-vacant buildings or lots.

With a clearer understanding of a site’s condition and trajectory, it is possible to assess how each site and the larger urban system can best prioritize development planning by assessing mutual enhancement (appreciating) needs relative to overall

development operations and structures. The next section frames five development network *forms* (summarized in Table 2) that collectively support scaling, engagement, and coordination network functions (as discussed in Chapter 3).

Table 2: Categorical Framework of Local Development Network Forms					
Component		Function	Indicators	Nodes	Links
1	Networks of Centers	Organize Space and Movement	Physical route betweenness; Accessibility; Connectivity	Urban Villages	Streets
2	Networks of Land Use	Organize Activity through Built Form and Open Spaces.	Square footage of commercial; public open space; vacant buildings;	Buildings, Lots, Parks, site attractions	Paths and walks
3	Social Networks of Cooperative Behavior	Organize Population and Expertise into Stable and Fluctuating Social Structures.	Facilitate partnering, contributions, and exchanges by facilitating behavioral norms and symbols of trust in system, future, and reputable individuals.	People Structured Activity Foci/Group	Relationships Exchanges
4	Networks of Perception and Discovery	Organize Information and Communication of Market and Resource Situational Awareness	Capacities for detecting key signals like market and resource trends. Capacities for experimenting with new markets and resources.	Media, Organizations, Schools, Markets, Studios, Laboratories Public Space	Sales Signals and feedbacks Innovation, Research & Development Ties
5	Activity Coordination Networks	Organize Organization and Planning	Individual and firm teaming to develop signals into markets and markets into opportunity: Jobs, wages, property values, investment rates of return.	Individuals Small and Medium Enterprises Institutions Firms Governments	Networking Investing Hiring Contracting Self-organizing

Forms of development networks can be represented, structured, and organized through different or *bipartite* categorical network forms like social *affiliation networks*

where people are nodes paired with a focal node of interaction like a group, activity, or location (Easley & Kleinberg 2010, p. 84). The focal node can be social, psychological, legal, and physical as long as it links an individual to particular structured activities (Feld 1981). Individuals can connect to such points to create paths—a series of links—to economic information, resources, or relationships.

Urban development planning to better organize experimental targeting and investment feedbacks must be concerned with particular affiliation networks. A categorical framework of *local development network forms* defines foci types that individuals can use to affiliate themselves with local business modeling efforts. Table 2 lists five examples drawn from the Roanoke study as well as urban design, economic development, and network literatures. With this information, the developmental services and network types each neighborhood center can supply to surrounding populations can be assessed to facilitate planning and design decisions.

Each of the urban village sites discussed represents different nodes within a *network of centers*. Dense urban populations require access to urban services, and many commercial services must be physically distributed throughout a region, creating at least the potential for neighborhood populations to focus these activities in a conveniently central location. Regional development overall is largely organized by the links between different neighborhood center sites and central business districts as these provide diverse focal points to connect with their respective affiliated service populations. A stronger West End center can strengthen the spatial and commercial connections of Grandin to downtown Roanoke, for example. Visitors can easily visit both sites, strengthening the commercial pull overall.

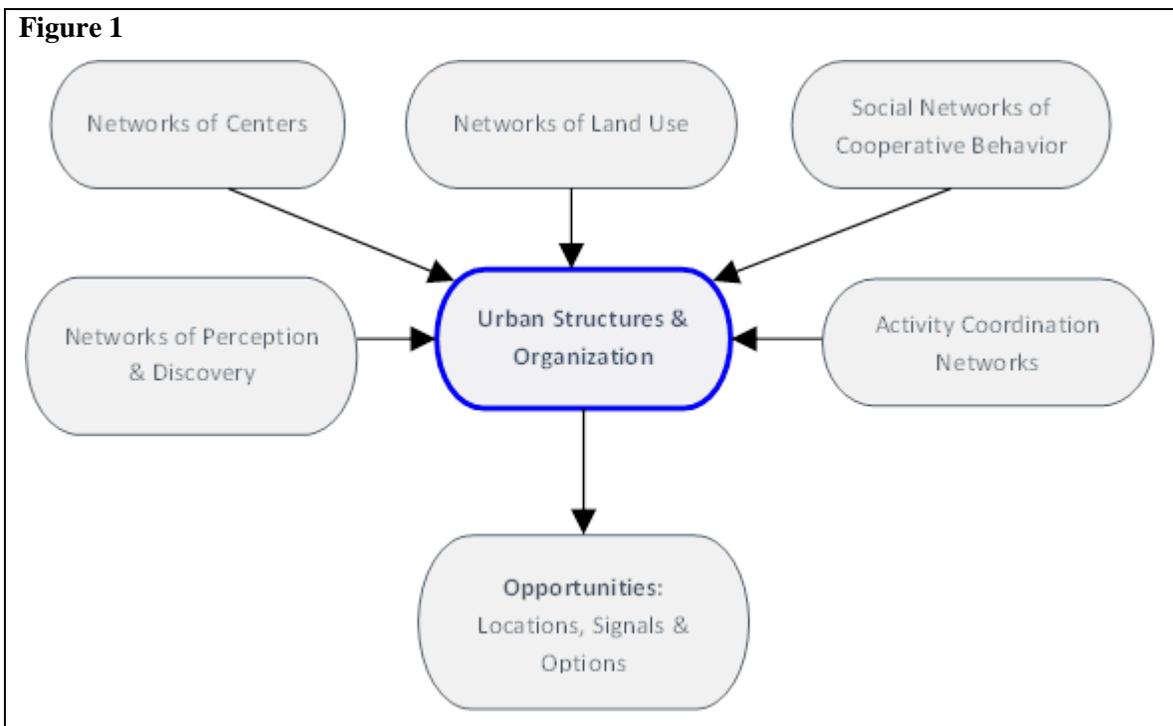
Within each local site, the *networks of land use* again link populations spatially, but this time at the scale of particular buildings, pedestrian paths, public spaces, and other sites within commercial districts that focus interactions with place. Through the specific designs, structures, capacities, and supported activities and uses of a site, an individual's potential economic affiliations can be limited or facilitated. In one sense this network form indicates how well physical facilities and qualities in a neighborhood center cooperate with experimental targeting goals. Grandin supports land uses of commercial activity, but as it prospers there may not be enough vacant or developable buildings

available. Those seeking to establish new businesses would need to affiliate themselves in an open building or site somewhere else, strengthening appreciating and targeting investments at that different site and increasing the overall level of activities there. This would, in turn, impact the neighboring businesses, sites, and social activities.

To the extent that a site must support an economic activity, so too must that activity be a focus of a population of people. Different categories of structured development activities create social affiliation *networks of cooperative behavior*. These networks can create more links in a neighborhood by increasing the interactions between certain structured activities and other individuals engaged in those activities. For example, in Grandin, business owners can connect with the business association as a node, and through the association they can connect with other business owners individually. In the West End, residents can now interact with the local credit union, and thereby access investment resources. In 11th Street, relationships with a barber shop or nonprofit are being harnessed to further socially tie individuals to hiring and support activities. By engaging in a structured activity or group, individuals have the potential to further densify and cluster social networks between other individuals affiliated with that focus of activity. This potential can improve social network levels of scale, engagement, and organizational strength in a community towards pursuing more resources and services.

A particular form of social network cooperation is essential for scaling levels of experimental targeting in a location. *Networks of perception and discovery* describe the affiliation nodes that connect individuals to structured experimental targeting activity nodes that gather individuals into groups working to develop new products and services, or discover other markets for existing business. Specifically, teams or institutions undertaking business information tracking, business model experimentation, product and service development, as well as activities to create new categories of customers or suppliers would all form one side of a bipartite graph to which individuals can link to form an edge. Jane Jacobs (1969, p.50) termed such activities “new work,” which she saw as a kind of localized import substitution that allowed more resources (purchases and investment) to stay local and further diversify a regional economy. The more product and service research and development, production technology improvement, education and

new skill training, entrepreneurship, venture capital, and market research and testing in a region, the more potential that economy has to adjust its network forms to economic conditions provided there are suitable economic opportunities to pursue. To some extent this process is locally emergent, as it scales and replaces imports from other regions (Jacobs 2000). Individual searches—for sales and investment models through affiliations with groups, infrastructure, and other structured activity foci and institutions—when successful, can then subsequently attempt to scale locally through capital accumulation investments and imitation.



For development network forms like these to move individuals towards opportunities, a network for coordinating signaling is essential. With multiple commercial centers within a region and multiple sites in each neighborhood, where should a person go to seek a new business opportunity? What commercial activities and social affiliations are available in a city? What businesses are growing, shrinking, or changing, and what groups are engaged in identifying and studying these shifts? *Activity coordination networks* serve the purpose of relaying information from these spatial and social affiliation networks to individuals to support their decision-making. What forms do

these networks between networks take in an area, and how well are they functioning throughout an urban population? Business information is relayed through markets, newspapers, government reports, emails, local signage, word of mouth, social media, street and shopping activity, even illegal activities in parks, and the internet and smartphone tools can facilitate much of this signaling on a daily basis. But are these organizing and communicating signals actually processing this information into usable patterns so individuals and groups can navigate or search to connect to an opportunity of interest? In many cases, the network boundaries of information signaling in neighborhoods mirror the spatial boundaries of specific economic activities and prosperity. A network development approach like the proposed West End “info nodes” could overtly signal to individuals available connections to different kinds of regional opportunities at the local level (See Chapter 6).

Conclusion

What development information dynamics occurred at the study sites? From a network perspective, experimental targeting activities attempt to form edges between different forms of networks to organize economic activity. The more those experiments in finding customers and markets succeed, the more appreciating feedbacks signal increases in the levels of capital available. More investments can be leveraged towards the engagement of more people and resources towards more business experiments to perceive more opportunities and to improve scale efficiencies. The more existing economic patterns fade, the more depreciating feedbacks can reverse engagement, perception, and scale supports regionally or within particular communities until development ceases.

The development status, trajectory, and capacity for transformation of each commercial neighborhood’s network structures determines much of the economic potential for businesses, quality of life for residents, and attractions for regional customers. The position of the City of Roanoke at larger geographic scales was less of a planning issue for commercial urban service providers as reflected in interviews. For investors and residents of the city, where it fit nationally or globally, was a topic for more questions than convictions. This remains a substantial research challenge and limitation.

Globalization and online commerce remained outside the scope of this study, and given their increasing importance a better understanding of extra-regional network impacts on local development impacts need to be better theorized relative to these studies.

Many Grandin respondents thought that a turnaround point had been reached in the last five years or so, but they wondered where jobs for highly educated young family members would come in time to provide them with the option of staying. Many mentioned enhancing the airport and passenger rail as important. Improvements to upgrade the stock of historically neglected people and buildings have been uneven, and commerce will have to enhance local appreciation both in value and perspective to sustain investment and other development feedbacks to avoid falling back into communally destructive ruts. As a contribution, identifying gaps in the network forms needed to support many new business activities can support local planning towards coordination and scaling efforts, and support additional research towards grounding development into more formal network planning tools and theory.

References

- Easley, D., & Kleinberg, J. (2010). *Networks, crowds, and markets: Reasoning about a highly connected world*. New York: Cambridge University Press.
- ELA - Virginia Society AIA Emerging Leaders in Architecture (2013). West End Village: A campaign to change perception. Retrieved from: <http://www.roanokeva.gov/DocumentCenter/Home/View/433>
- Feld, S. L. (1981). The focused organization of social ties. *American Journal of Sociology*, 86(5), 1015-1035. doi:10.1086/227352
- Fullilove, M. T. (2004). *Root shock: How tearing up city neighborhoods hurts America, and what we can do about it* (1st ed.). New York: One World/Ballantine Books: 71-100.
- Jacobs, J. (1969). *The economy of cities*. New York: Random House.
- Jacobs, J. (2000). *The nature of economies*. New York: Modern Library.
- Miller, J. H. (2016). *A crude look at the whole: The science of complex systems in business, life, and society*. New York: Basic Books.
- Neal, Z. P. (2013). *The connected city: How networks are shaping the modern metropolis*. GB: Routledge Ltd. doi:10.4324/9780203101728.
- Olson, B., Cooper, D., Viola, J. & Clark, B. (2015). Community Narratives. In Glenwick, D. S., & Jason, L. A. (Editors). *Handbook of methodological approaches to community-based research: Qualitative, quantitative, and mixed methods*. Oxford University Press: 43-52.
- van der Kolk, B. (2009) Afterword. In Courtois, C. A., & Ford, J. D. (Editors). *Treating complex traumatic stress disorders: Scientific foundations and therapeutic models*. New York: Guilford Publications: 455 – 467.

Chapter 5: Urban Development Agent-based Modeling for Building, Population, & Business Affiliation Matching

Introduction

The development planning of urban space, communities, and economies is extremely challenging given that each of these sectors affects one another while being challenging individually. Globally, exploding urban population growth, challenging environmental dynamics, transformative building technologies, and changing commercial behaviors create new contexts and significant opportunities for innovation in the scholarship and practice of economic and community development. Computational modeling, or simulation science, has certain epistemological strengths suited for discovering, layering, or linking different development research theories and methodologies.

Because of urban system complexity and coevolving variables (Batty & Marshall 2012), simulation science is one of the few tools capable of researching contemporary development interactions at street and regional scales simultaneously. What follows is a framework to apply computational social science concepts like agent-based modeling (ABM) methodology and research design in the context of development planning research. Within the short scope here, this primer is designed to facilitate further theoretical and methodological exploration.

While much has been learned from regression models and qualitative research, the complex and layered interactions of locational, aesthetic, technical, financial and behavioral factors among others are difficult to study with sufficient granularity. ABMs give a researcher a tool to imagine and explore the push and pull factors of a multitude of changes to a business and its relative location, as well as how those dynamics can affect a neighborhood and beyond. The changes in human behavior at the micro-level in response to economic or social shifts happen at street and face-to-face scale, and statistical analysis of large populations can lose critical local contextual detail and counterfactuals under the weight of averages, confidence intervals, and non-causal associations. This makes local development planning particularly challenging, as location, population, and distribution patterns and priorities are difficult to specify with such statistical models.

While more regional and global or macro-levels of statistical analysis (i.e., employment, wages, industrial sectors, etc.) remain essential development assessment tools, the research capacity to clarify internal structures and interactions are increasingly important for clarifying mutually dependent dynamics. At minimum, the development literature needs to better bridge research between social (Feldman and Zoller 2012), infrastructure (Coward and Salingaros 2004), and expertise networks (Huggins and Thompson 2015) as well as commercial neighborhood environments (Dovey and Wood 2015).

The research objective here is to conceptualize approaches to model multiple urban development capabilities computationally. The discussion below explores the theoretical underpinnings of computational social science and modeling followed by practical research design elements for agent-based approaches to urban development research. Emerging interdisciplinary tools and approaches are described to facilitate more comprehensive and collaborative research moving forward.

Subsequently, an urban scenario is described and a proposed ABM introduced to compare differences in development outcomes between changes in social, business, or spatial network elements. The two research questions for the model are a) *how does local spatial organization affect economic social affiliation networks and population distributions*, and b) *how does local population organization affect economic affiliations and business distributions*. The advantages and limitations of a modeling approach to studying these dynamics are then discussed and summarized.

Social Science Modeling Theory

Whereas development research has historically been concerned with urban economics, real estate finance, and incentive and targeting policy, new datasets and analytical tools and the potential to collaborate with those in computer science radically opens the possibilities for the creation of new knowledge. Urban simulations have been used to identify potential policies to control diffusion (e.g. the spread of an epidemic) trends through a population (Epstein 2009). Economically, they have also been utilized to study job search and hiring outcomes as influenced by transportation between residence and employer locations (Tilahun and Levinson 2013). Still others have been applied to

studying disaster response strategies that examined how residents moved in urban space following a hypothetical nuclear explosion (Lewis et al. 2013). Though such models can be extremely sophisticated computationally, urban theory can support timely advances in such research with broader collaborations between disciplines.

As a unifying research principle, Joshua Epstein (2008) notes in his helpful “Why Model” essay that anyone and everyone who conceptualizes a social dynamic is running a model. He continues that for most people such models are implicit; it can be unclear what their assumptions are, and what their internal consistency, logical consequences, and relations to real-world data could be. As Lazer et al. (2009) discuss, new forms and scales of digital data tracking are becoming increasingly embedded in global corporate services like Google or Facebook. They term this effort to collect and analyze massive amounts of societal data *computational social science*. There is substantial promise to integrate digital data tracking platforms and digital models of complex patterns to perform a variety of useful functions from prediction to diagnostics to scenario planning.

Axelrod and Cohen (1999, p. 7) describe complex systems as ones in which there are strong interactions between its component elements. These interactions often generate diversity enhancing *variation* and diversity reducing *selection* pressures among elements which can shift if the larger system environment experiences change. When a system has a population of active *agents* pursuing goal-oriented behaviors or *strategies*, the strategies that achieve some success in response to a system reveal *adaptation*. Together these elements form a complex adaptive system. Development agent populations include entrepreneurs, small businesses, firms, community neighbors, workers, customers, suppliers, financiers, regulators, planners, etc. Their strategies may be related to changing markets, technologies, products and services, resources, buildings, environments, networks, policy incentives, and location as important variables. Development systems remain wide open to further exploration of these relationships and interactions of the agents, strategies, settings, and variation and selection dynamics.

Additionally, physical environments like commercial buildings can also function as stationary “agents” from a programming standpoint. Through facades, architectural programs, and material conditions, and so on, a building can attract and retain or repel other mobile agents depending on the interaction properties present. A building by its

nature can attract a use which in turn attracts its further development and contacts over time. Internal spatial geometry, economic patterns, weather, and time all can play a role in people's economic use of buildings, and a commercial building's use of people through what Brand (1994, p. 164) called a certain "coevolving volatility."

Since the processes of coevolution exist on every scale, development complexity can be explored from individual buildings through the economic dynamics of an entire country (Hausmann et al. 2013). Hence, the biggest barrier to more development modeling studies has perhaps been the research challenges of analyzing coevolution.

Development Coevolution and ABM Complexity

Development coevolution and its resulting complexity is a product of nonlinear dynamics. Linear dynamics have variables with predictable independent/dependent relationships, while nonlinear dynamics are co-dependent. Each variable can respond differently to different situations. Situational inputs drive behavioral outputs that become the next situational inputs in a *feedback* loop. For certain patterns within complex adaptive systems—whether real-world or simulated, there are only two dominant types of nonlinear feedbacks.

The first sort of feedback is a reifying or amplifying *positive feedback*. Positive feedbacks occur when a signal generates behavioral responses emphasizing more of the same, and can thus yield exponential or logarithmic *growth* or *decline*. The term positive is thus a value-neutral term and does not refer to the policy desirability of such feedbacks. For example, gentrification pressures, where increasing rents can reinforce via social status or consumer attraction signals, are a familiar force to be reckoned with in development studies. Conversely, job losses, high crime rates, failing schools, and dropping property values can signal a race to the exits for more mobile residents that can quickly overwhelm many community development policy intervention strategies.

The second feedback, *negative feedback*, functions to keep a system's dynamic within a limited, or regulated, range. Just as a thermostat functions to keep a room's temperature not too high or not too low, or the human body burns energy or sweats to keep its temperature in a given range. This is done through signal *thresholds* or trigger or tipping points that counter or regulate behaviors when certain value states are reached. As

cut points have been estimated via logistical regression studies, simulations can explore these previously identified thresholds to more systematically integrate previous work as well as isolate key values for further mixed method study and verification. Negative feedbacks in development could include the fundamental supply and demand pricing dynamic or tradeoffs between government services and taxes, for example. Good services could attract new residents and growth, but the increasingly high taxes to pay for them would likely disincentivize continued growth, requiring attracting either richer residents, lower taxes and services, or some way to lower the costs of those services.

What simulations allow is a testing of both potential causative dynamics to identify candidate feedbacks for further research and validation, as well as explorations of other signals (and signal distributions within certain boundaries or networks) to determine potential mitigation dynamics. If/then algorithms that link a system's changes over time as feedbacks are the drivers of many nonlinear effects like the positive feedback "rich get richer, poor get poorer effects." They are also the source code of imitative feedbacks like swarming behaviors and cascading domino effects. This has implications for development studies which explore diffusion and imitation dynamics.

These sorts of simulated behaviors can be helpful for exploring affordable business location supply and demand dynamics. In addition to exploring rates of change in rents and new development, researchers have the option to add different kinds of agents with different wealth, behavioral options, and signals. Of critical importance are the boundaries that define an area. If a particular community finds itself trendy and demand is increasing, is the area affected defined by government boundaries, transportation costs, or some other culturally definition? Could financial feedback policies, such as government taxes, proffers, or value capture tools, fund new development patterns by linking thresholds in rent increases or development fees to investments in other underinvested areas of town? What are the potential effects of these policies? Are gentrification pressures mitigated, redistributed, or accelerated? What about poverty concentration levels?

In addition to commercial property markets, technology diffusion, and policy exploration, computer modeling is also an important research approach for exploring appropriate residential and commercial zoning arrangements. By changing different

building densities, transportation links, parks, and shopping amenities to look at different urban development scenarios and community interaction dynamics, researchers can explore both agent behavior and network optimization parameters.

Epstein (2006, p. 38) describes *agent-based modeling* as a specific subset of modeling for exploring population, location, and strategy behavioral questions. ABMs have been defined by Railsback and Grimm (2012, p. 10) as “models where individuals or agents are described as unique and autonomous entities that usually interact with each other and their environment locally.” Thus, an ABM’s simplest elements are the agents, environments, and interaction elements for a given research subject. For development, the key strengths of generative ABM include the capacity to investigate mutually interacting variables such as the interactive coevolving relationships listed and described in Table 1.

Table 1. Examples of coevolving development relationships	
Scale relationships	individual components (e.g., business) to rest of system (city) or a subsystem (neighborhood, market, ecosystem);
Temporal relationships	present to past patterns and potential future pattern parameters;
Visible relationships	a commercial building’s aesthetic form to users as well as passing pedestrians in terms of its information signaling (ornament, behavior, visibility, etc.);
Social relationships	development of cultural group fashions, behaviors, accessibility, and territories (do they facilitate or inhibit certain social network practices?);
Financial relationships	locational, aesthetic, and functional influences on rents and property values;
Functional relationships	development to support lifestyles within commercial sites; and
Policy information relationships	between different social roles (agents) in development planning from government planners, entrepreneurs, firms, property developers, technology designers, builders, and financiers to relevant information and planning participation.

A great strength of ABM is the capacity for modeling change and potential relationships, not just static, linear statistical descriptions of situational snapshots drawn from whenever data were collected. For example, local development research is increasingly focused on urban design (spatial) dynamics (Dovey and Wood 2015), social network dynamics (Feldman and Zoller 2012), and economic demand dynamics (Dhar et al. 2014). With these factors setting the context for what Simon (1991, p. 132) termed *bounded rationality*, where human beings have limited capacities to adapt to complex environments. ABM has the capacity to explore the interrelated/coevolving urban development dynamics generated from spatial boundaries, network interactions, and bounded rationality (See Table 2 below). Through an ABM, spatial graphs and social data can be modeled and statically compared to understand different possible input situations (e.g., population behaviors or building distributions) and resulting outcomes for various agents. At the end of the study, the geographic and network information would be stored, along with the statistical findings to support further research and planning applications.

Table 2: Features of Agent-Based Models
<ol style="list-style-type: none"> 1. Heterogeneity--individuals explicitly represented and offer differ in multiple ways 2. Autonomy—no central control; macro & micro levels coevolve 3. Explicit space—local geometry relations, rules, & structures well-defined 4. Local interactions—non-uniform mixing: typical interactions with neighboring elements 5. Bounded rationality—two components: bounded information & limited computing power by individual agents and groups. 6. Non-equilibrium dynamics—tipping phenomena, emergent macro regularity, & large-scale transitioning.
<p><i>Source: Epstein, 2006, p. 51-52</i></p>

For specific research relating to overtly spatial environments such as development, ABM tools like NetLogo, a software package designed for simple but

powerful ABM creation by Wilensky (1999), provide important functionality of great relevance for contemporary research challenges. For planning purposes, NetLogo’s capacity for integration with geographical information systems (GIS), is a major asset. GIS data is relatively stable and slow changing relative to social or economic data. Geocoding can help to organize behavioral patterns, data outputs, and pattern perception into more familiar visual forms; all while retaining extensive data sets suitable for statistical analysis.

Model Elements and Description

Human agents interact with urban systems at all levels—physical, social, financial, and informational. By conceptualizing how *housing, employment, or commercial spatial opportunities* and their associated costs are distributed across urban space, an ABM can how to enhance spatial building patterns to enhance individual access to appropriate housing and commercial activities. How can these urban development network interactions be modeled?

Railsback and Grimm (2012) note that agents do not (typically) interact with every other agent all at once, but with nearby neighboring agents and environments or perhaps with those to which it is directly connected through *networks* of specific links (or *edges*) and *nodes* such as locations, agents, or potentially some form of simulated resource.

Table 3 - ABM Components: Agents, Environments, and Interactions				
<i>Components</i>	<i>Agents</i>	<i>Environments</i>	<i>Interactions</i>	
	Properties	Spatial	Agent-agent	Agent-self
	Behaviors	Network	Agent-environment	Environment-self
	Collections	Special	Environment-environment	
<i>Source: Wilensky & Rand (2015)</i>				

In an ABM, components define the agents, the spatial setting, and network interaction structures and economic interaction rules (See Table 3 above). As

computational models, each component needs definitions for these properties and actions. By organizing some of the research components into ABM descriptions and dynamics, we can simulate where something is, how it is connected to the rest of the system, and how, where, when, and to what extent exchanges occur with other components. For development planners, the main interest is necessarily a model's usefulness as a tool for discovery. The common ground of both planners and computational modelers are the main data inputs and processes that need to be understood to understand an output pattern from either real-world or simulated phenomena. As a thinking practice, modeling forces very precise analysis concerning what is essential, how things work, and how such things can be represented symbolically and mathematically.

For these reasons, modeling is often an extremely iterative and cautious art. From simple beginnings, important model innovations can take many years to gain wider acceptance and application. By this standard the conceptual effort here is a wildly creative act. It is not a good way to begin programming the code of a model, or rigorously support its disciplinary assumptions. It is, however, an excellent way to jump in to stimulate further thinking. As a demonstration of these processes, a hypothetical scenario for different agents is introduced and subsequently converted into an ABM framework below.

Urban Development Scenario

Due to lease cost difficulties with their former landlord, an existing restaurant owner needs a new business location, preferably as close as possible to existing customers and/or large foot traffic of potential customers. The commercial areas that were the owner's first choices for a general location did not have any vacant buildings appropriate for the business, the owner must choose between a less appropriate building or a less appropriate neighborhood. The owner thinks that a great building extremely near their first choice community will be accessible enough to keep most of their existing customers. The business's success over time could be improved if other businesses also relocated or improved their customer traffic nearby, and one community about a mile from the ideal location has been getting a lot of government and nonprofit investment the past few years. There is, however, a nearby public housing estate, but it too has been

recently renovated. The owner decides that despite the bad reputation of the area, the investment trends are strong enough to signal a welcoming setting to customers and other complementary businesses. This owner knows their customers and their business very well, and they are confident they can make this less than ideal situation work. If that is, they can hire the right people.

At the same time, a new graduate is moving into the region, and they looking for a job and place to live, preferably near one another. They are considering moving to a tourist area with more job opportunities in a few years, and restaurant jobs are particularly attractive. Ideally, a restaurant with affluent customers and lots of opportunities for learning more about higher end cuisine would be great. They do not know anyone locally yet and gas money is tight, so the student takes the bus around town looking at apartments and nearby neighborhood restaurants. Unfortunately, the best restaurants are typically only close to very expensive or very crowded housing. A couple of affordable communities have seen new housing construction and repair in places, and one storefront has a grand opening notice listing a local restaurant that is relocating.

A public housing resident of the city is enormously frustrated. They finished a jobs program several months ago, but a major local employer relocated and they have had no luck competing against the more experienced laid-off workers. They could move out of town, but the resident's mother can watch her kids when they get sick or she has an interview after school. Her uncle takes her to go grocery shopping each weekend in his car since the nearest stores, laundry, and other businesses are miles away. If she moved she would also have to reapply for benefits and get on the waiting lists for housing. Depending on the pay and the hours her income with assistance might be less than what she has. That is assuming she could find work quickly in a place where she does not know anyone. Her kids would have to find new friends in school too. Truthfully, there is no money for a move anyway. One of her neighbors says a new restaurant is moving into the old Italian restaurant building 8 blocks away that had been boarded up for 15 years. She has never worked in a restaurant before, but she hopes her participation in the jobs program will convince the restaurant manager that she is hard-working and eager to

learn. If she can work nearby she won't have to spend 45 minutes each way by bus, and she can have more time to help her kids with homework.

Each of these agents is searching for a solution to their own personal economic development dilemma. The restaurant establishment owner is trying to decide the best site to move their restaurant to, but there is a conflict between the perceived suitability of different commercial areas, or the regional network of commercial centers, and the availability of a suitable building. The newcomer is trying to connect to employment that is located near an attractive, active, and well-serviced location to live as well. But they cannot afford or find many residences or jobs that quite work except in areas near where housing and business vacancies are linked. For current residents of these underperforming areas, the lack of experience, local commercial services and businesses, and available employment limits their economic opportunities year after year. To what extent can these agent's interacting, or complex, urban development problems be formally defined and simulated as networks to explore their personal and collective situational trade-offs, advantages, and disadvantages?

From a development perspective, each of these agents is faced with simultaneous spatial, social, and business access problems. The owner needs a neighborhood site for the store, a building suitable for their restaurant, and connections to supply and demand information sources. The neighborhood resident needs a place to work and local commercial services near their home. The graduate newcomer needs the same things as the public housing resident, but first, they have to pick a neighborhood. The subsequent ABM (Figure 1 and Model Steps below) is an attempt to simulate some of the key development dynamics which structure population, location, and activity interconnections, rules, and behaviors.

Model Steps

I. Model Structure (See Figure 1)

- A. Create 3 **urban centers** (Large circles) with a radius to simulate walkable distances.
- B. Create adjustable [X] number of immobile agent **buildings** (small squares) within a large rectangle at the center of each center, where X is set at the beginning of each model run.
- C. Create varying [X, Y, Z] populations and locations for three breeds of mobile

agents—**establisher**, **newcomer**, and **resident**. Resident populations are located along the interior of one of the center’s radius. The other two classes of unmatched agents are stochastically assigned to a center or a regional pool at the bottom left of the model.

D. Set initial state/attribute values for each agent type.

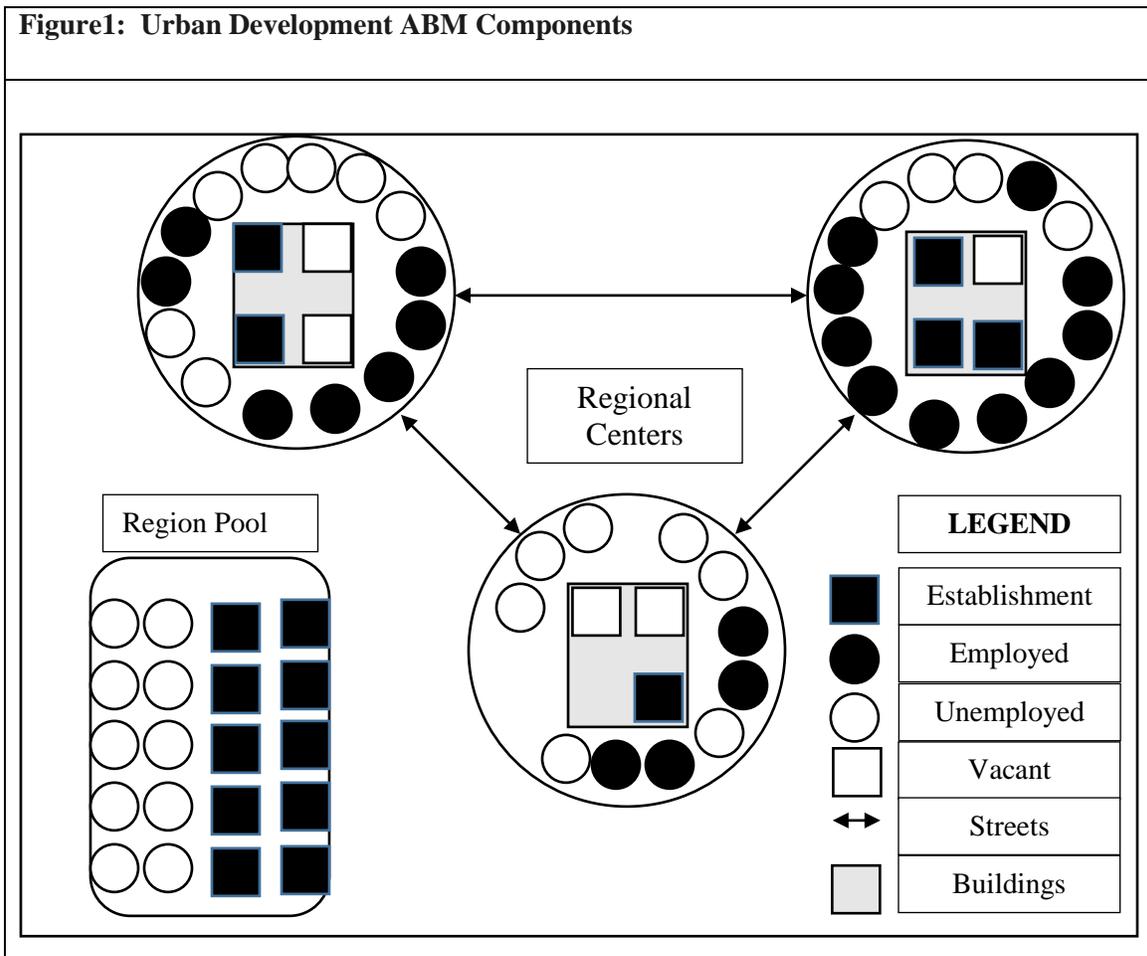
- **Building** *connection* states are coded as vacant [set connection = 0], or establishments [=1] if it is linked to an **establisher** agent. These now overlapping agents are coded as black small squares. They are also given *cost* values and *attraction* scores based on nearby establishments. If the adjacent buildings are vacant [+0], if an establishment [+10 to cost and attraction]. If cost thresholds reach level X (variable settings), a new vacant building is added to the center.
- As above, **Establisher** agent *connection* states are coded [=1] when occupying a building. A disconnected Establisher will connect to the best available vacant building based on its *attraction – cost* score.
- Subsequently, each **establishment** can form an *affiliation* link with up to random value [e.g., random between 3-10] *residents* and/or *newcomers*.
- Linked **Establishments [Establishers+Buildings]** affiliate with the unaffiliated **Resident** or **Newcomer** in order of *experience*, assigned to that building’s Center radius.
- **Newcomers** move to a Center’s location based on the ratio of the (# unaffiliated population)/establishments + costs. If no establishment affiliations occur in 20 ticks, then recalculate Center location. If no connection in 100 ticks [die].
- **Resident** or **Newcomer** agents with *experience* = 100 or greater have a varying [X] chance of becoming an **Establisher**.

D. Generate outputs: building and mobile agent populations, network states, and values.

For this model, agent populations include three classes of mobile agents, two classes of immobile agents, and a multitude of associated different network nodes and edges. The model codes **buildings** as stationary agents whose properties include cost and attraction scores based on the number of surrounding active buildings (establishments). **Newcomer** agents try to link to buildings that match both a work location based on experience scores and the overall number of establishments (services). **Resident** agents need local access to establishment affiliations (employment) and establishments (services). **Establisher** agents try to link to buildings in areas of high attraction (business density) that they can afford according to their wealth scores. Unmatched resident and newcomer agents are coded as “displaced” if unmatched with a business for 20 model

rounds. The model stops when a majority of agent populations have been displaced or after 1000 rounds. The model interaction menu can be set for different initial populations and values for each of these properties, and different model data outputs and pattern distributions are then measured against one another to look for tipping points, feedback loops, and other important dynamics.

Figure1: Urban Development ABM Components



Due to positive feedback dynamics like accelerating investment (gentrification) or disinvestment (blight), there are a number of instances where urban villages track a development pattern which is harmful to many displaced or trapped residents as well as the region as a whole. Due to contagion pressures like increasing government assistance costs or unsustainable costs of living these local feedbacks can become regional development problems. In terms of planning needs, what is particularly interesting from a development standpoint are community centers. If stable, a community center can

continue to host ongoing business and human development without appreciation or depreciation pressures crowding out the fragile activities to establish careers and businesses within a particular spatially related urban context.

Previously (see Chapter 4), five different network forms were discussed. This model simulated the dynamics of three of them, the networks of center, networks of land use, and social affiliation networks of cooperation. This model does not capture product life cycle and economic sector shifts, so networks of perception and discovery and networks of activity coordination are not featured here but are discussed subsequently (see Chapter 6). As the previous section describes, models can flexibly be applied to the study of an increasing number of complex urban topics. For applied development, modeling tools could potentially help planners to make decisions as an extension of scenario planning and data tracking applications.

Models, Development, and Research Boundaries

The expense and data requirements to study these coevolving development patterns experimentally for actual urban sites would typically be enormous. However, ABM offers simple means of experimenting with structural elements in development. How many commercial buildings can be financially supported by a given neighborhood population? How would that vary by changing levels of income? With research questions like this, the complexity of the system stems in part from the many levels and many signals at work at any one time in any one place, and network theory and simulation systems provide many tools to conceptualize these for further study, including using GIS network analysis extensions (Sevtsuk and Mekonnen 2012).

Once the organizing structures of nodes, links, boundaries, and signals are theorized enough to begin thinking about constructing a spatial-based model, the behaviors of agents are thrust to the forefront. Capturing the important behavioral patterns as a code is its own challenge, but many existing models have established certain programming methods, strategies, and standards (see for example the NetLogo library in Wilensky 1999).

At the outset, the hardest design decision is how much complexity to attempt to capture in a model. The best models are necessarily as simple as possible. Simple

beginnings usually make the programs and findings easier to code, understand, test, validate, and expand. As a modeling exercise, these considerations are paramount. Before a model can be useful, it has to actually work computationally. This will always restrict the viability of using simulation to study many development topics. Contemporary urban innovation and information economy dynamics may be too abstract to simulate in combination with urban dynamics.

The inherent tradeoff between a research interest in urban complexity and simulation science's requirements for some measure of simplicity must remain a source of constant creative tension. As a potential contribution to development planning, the main interest is necessarily a model's usefulness as a tool for discovery. The common ground of both planners and computational modelers are the main data inputs and processes that need to be understood to understand an output pattern from either real-world or simulated phenomena. As a thinking practice, modeling forces very precise analysis concerning what is essential, how things work, and how such things can be represented symbolically and mathematically. Networks concepts make this formalization easier to graph and design.

For these reasons, modeling is often an extremely iterative and cautious art. From simple beginnings, important model innovations can take many years to gain wider acceptance and application. By this standard the conceptual effort here is a wildly creative act to explore potential research approaches.

Summary

This framework demonstrates an ABM simulation approach to explore multiple urban development capabilities computationally. With this tool, coevolving development outcomes could be explored between changes in populations, businesses, and spatial network elements. This, in turn, could help to explore research questions about how spatial organization affects population and business affiliations and how populations can affect business distributions. The trade-offs within and between urban business sites and neighboring sites can demonstrate how complexity can mount quickly within highly interactive and scaled situations.

For urban planners, it is a central problem to determine which regional center to better organize or strengthen to intensify and potentially better connect regional economic patterns as a whole. At the urban center level, latent site improvements could be formed from buildings, their businesses, and associated populations. Regional models could study investment patterns, regional land values, gentrification, segregation, building patterns, residential impacts, transportation, and a host of other socioeconomic dynamics and infrastructure impacts. A local model could explore many urban services access like banking, groceries, workplaces, pedestrian traffic, car and public transportation, businesses role-modeling, vacant business sites, business networking with other businesses, parking, rent dynamics, green space centers, and other urban design and social activity interactions. Again, however, it is best to limit the amount of complexity in an individual model.

Due to positive feedback dynamics like accelerating investment (gentrification) or disinvestment (blight), there are a number of instances where urban villages track a development pattern which is harmful to many displaced or trapped residents as well as the region as a whole. Due to contagion pressures like increasing government assistance costs or unsustainable costs of living these local feedbacks can become regional development problems.

The ABM urban development concept briefly introduced here needs extensive data as well as mathematical and programming development before implementation. But, the discussion may demonstrate a research process for how ABM might be applied to explore certain urban dynamics discovered through real-world research, but difficult to explore further by other means. As the model functionality is improved, and scale and complexity are added, it will be necessary to further draw on real-world data to guide model design decisions. Existing patterns can be the best teachers as to the key variables and dynamics which should be modeled.

In regard to urban systems, both development and modeling share the same goal. Are city economic needs coherent to decision-makers? Are those processes coherent enough to simulate? Urban complexity is enormously hard to study and even harder to generalize. The co-evolving contexts, initial states, and distribution variations are

constant sources of novelty. The urban development processes and loops can reduce, stabilize, or enhance this novelty. Simulation tools might show planners some fundamental ways to coherently explore this potential.

References

- Axelrod, R.M., and M.D. Cohen. 1999. *Harnessing Complexity: Organizational Implications of a Scientific Frontier*. New York: Free Press.
- Batty, M., and S. Marshall. 2012. "The Origins of Complexity Theory in Cities and Planning." In Portugali, J., Meyer, H., Stolk, E. and Tan, E. (Eds) *Complexity Theories of Cities Have Come of Age*, Berlin and Heidelberg: Springer-Verlag: 24–47.
- Brand, S. 1994. *How Buildings Learn: What Happens After They're Built*. New York: Viking.
- Coward, L., & Salingeros, N. 2004. "The information architecture of cities." *Journal of Information Science*, 30(2), 107-118.
- Dhar, V., Geva, T., Oestreicher-Singer, G., & Sundararajan, A. 2014. "Prediction in economic networks." *Information Systems Research*, 25(2), 264-284. doi:10.1287/isre.2013.0510
- Dovey, K., & Wood, S. 2015. "Creative multiplicities: Urban morphologies of creative clustering." *Journal of Urban Design*, 20(1), 52-74. doi:10.1080/13574809.2014.972346
- Epstein, J.M. 2006. *Generative Social Science: Studies in Agent-Based Computational Modeling*. Princeton, NJ: Princeton University Press.
- Epstein, J. 2008. "Why Model?" *JASSS-The Journal of Artificial Societies and Social Simulation* 11, no. 4.
- Epstein, J. 2009. "Modelling to Contain Pandemics" *Nature*, 460(7256), pp. 687-687. doi:10.1038/460687a
- Feldman, M., & Zoller, T. 2012. "Dealmakers in place: Social capital connections in regional entrepreneurial economies." *Regional Studies*, 46(1), 23-37. doi:10.1080/00343404.2011.607808
- Hausmann, R., Hidalgo, C., Bustos, S., Coscia, M., Chung, S., Jimenez, J., Simoes, A., & Yildirim, M. 2013. *The atlas of economic complexity: Mapping paths to prosperity*. US: MIT Press.
- Huggins, R., & Thompson, P. 2015. Entrepreneurship, innovation and regional growth: A network theory. *Small Business Economics*, 45(1).
- Lazer, D., A. (Sandy) Pentland, L. Adamic, S. Aral, A.L. Barabasi, D. Brewer, N. Christakis, N. Contractor, J. Fowler, M. Gutmann, T. Jebara, G. King, M. Macy, D. Roy, and M. Van Alstyne. 2009. "Life in the Network: The Coming Age of Computational Social Science." *Science* 323, no. 5915, pp. 721–23. doi:10.1126/science.1167742
- Lewis, B., S. Swarup, K. Bisset, S. Eubank, M. Marathe, and C. Barrett. 2013. "A Simulation Environment for the Dynamic Evaluation of Disaster Preparedness Policies and Interventions." *Journal of Public Health Management and Practice: JPHMP* 19 Suppl 2(2), pp. S42–48. doi:10.1097/PHH.0b013e31829398eb
- Railsback, S.F., and V. Grimm. 2012. *Agent-Based and Individual-Based Modeling: A Practical Introduction*. Princeton, NJ: Princeton University Press.
- Sevtsuk, A., and M. Mekonnen. 2012. "Urban Network Analysis Toolbox." *International Journal of Geomatics and Spatial Analysis* 22, no. 2, pp. 287–305. doi:10.3166/ig.22.287-305

- Simon, H. A. (1991). Bounded rationality and organizational learning. *Organization Science*, 2(1), 125-134. doi:10.1287/orsc.2.1.125
- Tilahun, N., and D. Levinson. 2013. "An Agent-Based Model of Origin Destination Estimation (ABODE)." *Journal of Transport and Land Use* 6, no. 1, pp. 73–88. Retrieved from <http://hdl.handle.net/11299/171178>. doi:10.5198/jtlu.v6i1.271
- Wilensky, U. 1999. "NetLogo." Center for Connected Learning and Computer-Based Modeling, Northwestern University. Evanston, IL. <https://ccl.northwestern.edu/netlogo/>
- Wilensky, U., and W. Rand. 2015. *Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo*. Cambridge, MA; London, England: The MIT Press.

Chapter 6: Computational Urban Development Planning - A Conceptual Framework for Regional & Local Network Analysis & Adaptation

Introduction: Regional Development Adaption and Computational Planning

Many United States (US) urban economies are struggling with obsolescence in physical infrastructure, human development, as well as business and social network characteristics required for renewal. Many smaller regions, throughout the Virginias and Carolinas in particular, have seen catastrophic employment losses in light industry (e.g., furniture and textiles), agriculture (e.g., tobacco), and resource extraction (e.g., coal) in rapid succession. With few discernable competitive or manufacturing advantages or alternatives for jobs, such regions with little experience or expertise in innovation enterprises are now forced to economically compete with those that do. For many smaller population or geographically peripheral regions, this has not proceeded well. Collective transformations of physical, social, and knowledge structures towards new economic patterns involve enormous training and infrastructure investments in money and time, assuming they are available. Furthermore, some populations, relationships, and sites resist such systematic transformations of their common ways of life. This means that in addition to overcoming cultural resistance or individual motivation challenges, development planning must somehow harness regional scale investment as well as individual behavior towards synchronized transformations in capital towards economic sectors with expanding opportunities and wages.

Functionally, the jobs and resources people seek, the businesses they start, and the associated investments families, firms, and governments make financially can be facilitated by network processes. Such networks connect people to available market and customer information (in various forms) to make targeting decisions relative to perceived and accessible assets and opportunities. Sometimes such information and decisions may be obsolete, mistaken, contradictory, culturally biased, personally odious, and/or have very little to do with livability priorities and motivations. These challenges can inhibit successful economic outcomes. In order for urban development planning to contribute to enhanced adaptive capacities for regional economies, it must better theorize how patterns of global, regional, and local economic information can be better perceived, interpreted,

and updated systemically. Only well-structured and distributed market signals can be systematically perceived, distributed, and then processed or *computed* to synchronize regional and local patterns of individual, enterprise, and government investment as ongoing adaptation. A key question to advance this research is *how can urban development planning be defined computationally, and how might urban development planning systems be computationally enhanced towards adaptive functions at multiple spatial levels?*

What follows is a theoretical outline to frame and propose a computational complex adaptive systems methodological approach to urban development planning, or as a *network-oriented development* approach to synchronize economic situational information, policy, and populations. After discussing terms, concepts, methods, a conceptual definition of computational urban development planning (CUDP) and a proposed framework is introduced to guide network decisions. Planners must make network decisions to track economic change and construct shared narratives of what changes might mean for local economic actors and assets. The narratives, as scenario models, communicate individual and collective intentions for the future. Interpreting narratives through network data tracking and analysis can support better synchronizing investments towards adaptive capacity enhancements and development planning.

Theoretical Review

In the United States, regions from great to small in population size are faced with ongoing economic transformation. Regional adaptive development theory describes three different phases of development which regions can pass through (Acs et al., 2008; Simmie and Martin, 2010). *Factor-driven growth* is centered on economic activities related to basic competitive advantages. *Efficiency-driven growth* standardizes and scales technology, labor, and infrastructure to compete on price or quality or improve distribution coordination. This productivity typically moves to areas with lower ownership or transaction costs, because the knowledge embedded in these increasingly standardized processes becomes more easily imitated or exported. The third phase of regional development within this theory is *innovation-driven*, where competitive advantage is embedded in the ability to invent or discover new products, processes,

materials, markets, services, applications, and so on. Innovations often require extensive subsequent refinement in expertise and learning standardization before techniques are easily transferable to factor and efficiency competitive region that can then pressure incumbent firms' and regions' market shares and/or profits.

The economist Robert Solow (1957) argued that there were three ways to increase the productivity of an economy which parallel adaptive development theory: expand the population of the workforce (factor), invest capital into productive infrastructures to make labor more productive (efficient), or increase the amount of knowledge (innovation) in that economy. This latter innovation phase of productivity has become an increasingly important developmental path moving forward for regions exposed to pressures in wages, employment, and business location attraction and retention problems. Development planning theory has struggled to provide applied approaches and strategic guidance for systemic innovation to regions and constituent municipalities and neighborhoods to renew wage, employment, and entrepreneurship levels (Rubin, 1988).

There has been limited clarity relative to different points of targeting investment emphasis or potential industry trajectories suggested by development strategies (Johnson, 2009). This is because as competitive pressures on economic advantage factors or productive efficiencies fade in many regions, merely copying other successful regional models like Silicon Valley often fails to effectively produce innovation or creative assets adequate to replace what is lost. Innovation or information assets such as knowledge, experience, cognitive diversity, technology, etc. are not very easy to “plug and play,” or insert, import, recruit, buy, or otherwise spatially substitute across locations in brief time frames (Storper, 2011, p. 336). Highly successful regions show considerable collective business network strengths where the structures and relationships of business and social networks of economic actors enhance or inhibit the innovative and technical capacities of individual agents' expertise (Huggins and Thompson, 2015). This is shaped through the network connections and resulting boundaries and disconnects that structure the distributions, cooperation, and rationalization of economic development activities. This, in turn, organizes opportunities to develop *human capital* in the form of skills, experience, education and professional knowledge and experience (Hidalgo, 2015)

Regional networks structure the *bounded distributions* of resources and information in space and populations to create interacting economic scales (Salingaros, 2012). The resulting spatial and social patterns coevolve with technology and supply and demand competition dynamics to form local market patterns and resulting *bounded cooperation* patterns of economic engagement (Nowak, 2011). Fluctuations in markets, technology, and associated networks evolve as do resulting signals and shifts in flow. These changes are often too great or too small in scope for individuals or even groups to recognize, interpret, and act upon. Simon's (1991, p. 132) *bounded rationality* refers to the ways that complex environmental conditions limit human capacities to process information to guide economic behaviors. The tools to expand human adaptive capacities include networks for tracking market conditions, contextually framing market data, and collaborative decision-making.

These factors mix in important ways. Ortman et al. (2015), in a review of ancient Central American settlements, concluded that urban productivity and spatial structure adjusts to reduced transportation costs. Over time, the more technology and structural change facilitate transportation, the more land area a settlement can take up. This, in turn, facilitates larger social networks through enhancing interaction activity that can support more efficient and productive economic activities. This suggests that in order to understand which cues, behaviors, and associated social networks there are, we have to understand the social and group scales and network structures of information exchange and processing strategies.

To some extent these mismatches between economic activities and regional structural organization are inherent to urban spatial and physical infrastructures as well as social or informational network structures. Coward and Salingaros (2004) have written about a three-way optimization problem in which urban areas cannot optimize their physical network structures for present economic efficiencies, while simultaneously staying flexible for future needs, and affordably repurposing assets from the past. This last issue means physical infrastructures, or *physical capital* assets in concrete and steel, are typically expensive to build, maintain, and change as new economic activities and patterns emerge. Other forms of capital—technology, business and social relationships, institutional and neighborhood development cooperation, and finance may be similarly

subject to being out of synch with regional competitive advantage. The challenge to better synchronize and transform capital is thus both a challenge *across* scales from street to globe, *between* communities linked to form regions, and *through* time as economic patterns evolve.

Theoretical Framework: Structuring Computational Urban Development Planning

Development planning means that locations, populations, and expertise must somehow be brought into an economically functional alignment on an ongoing, flexible basis. Storper (2013, p. 66) wrote that “The overarching methodological challenge is to link epistemology, theory, modeling, and data together in a way that enables plausible stories about change and development to be told.” Development frameworks are important not just academically, but also for the specific analytical tasks of business strategy, entrepreneurship, workforce training, and other individual and team adaptations. Within innovation-driven economies, sites, people, and organizational processes must be prepared, repaired, or adapted consistently relative to different market opportunities and needs. The “methodological challenge” to frame and link these concepts into a useful model narrative begins with coherent theory for defining development behaviors, behavior groups linked to those behaviors, and critical behavior sites related to development. Networks are a useful theoretical and methodological tool to systematize this planning.

Signal and Perception Programs

To understand what urban development should compute to support regional adaptation and planning, there are a number of epistemic/information problems which must be addressed systematically. An initial research topic involves the *perception and analytical systems* for measuring both locally specific and broader contextual change within a regional urban economy. In order to align populations, places, and knowledge, some form of regional “big picture” relating to potential economic opportunities is important. What products and services will drive future development? What kinds of workforce needs are anticipated? What infrastructure and training investments are required to compete? How will the region finance investments? Though this big picture is

critical, regional outcomes are the products of complex network interactions happening at much smaller scales, and subject to rapid shifts as conditions change which may alter the accuracy of any planning or prognosis. These network events typically happen at perception and information framing levels of individuals, groups, and firms (Randall et al., 2011). Systems can network to share market information and investment intentions to generate different situational reports and coordinate responses between and among these levels (Pentland, 2008).

How information moves in an organization, including what people signal, whom they signal, and how they attend to signals is a major feature of any system's functions (Keegan and Leahy, 2009, p. 17). This *signaling activity* can help people make sense of the world and decide how to operate in it if signals are matched to particular behaviors. Hidalgo (2015) defines *computing* systems as systems where the outputs or generated patterns are conditional on the signal inputs. Usually formalized as "If/Then" signal processing rules called *algorithms* or classifier *programs*, semi-autonomous individuals or *agents* can utilize such decision rules to guide their interactions with other agents and portions of their environment (Holland 2012). Urban characteristics that directly relate signal inputs and outputs for urban development agents and behavior programs can be formalized as networks, algorithms, and associated computations.

For example, agents seeking to adapt to local workforce conditions might compute decisions to seek more education, another job, or move to another region based on various situational signal cues like hiring patterns among their work peers, neighbors, or the local employment rates. An employee agent algorithm might be formalized as: *if layoffs occur at work, then seek a new employer*. Complex behaviors are structured by the combination of a situational cue, the "If" status, state, or condition variable, which once triggered cues a response by a subject's "Then" classifier program response. This response subsequently that sets off new situational inputs or "If" conditions for neighboring agents and upper and lower scales that affects their status and responses. Computations are "feedback loops" (system condition outputs become the next situational inputs) that either accelerate (positive feedbacks) or regulate (negative feedbacks) systemic shifts and change.

Urban computation, therefore, does not refer to the exclusive use of computer hardware and software to make decisions, but rather the way data are detected, organized, and processed through various steps to reach a decision outcome. These steps are both overtly quantitative and also qualitative in terms of the criteria such as human needs and commercial forces that can require ongoing adjustment (Salingaros, 2012, p. 247-248). In this sense, Salingaros (2012) argues that urban decisions are computational in that they compute the local and inter-scalar connections (p. 259) as well as the larger-scale system coherence (p. 267). The interactive, step-wise processes compare incoming data about the situation and circumstances of an urban development situation and scenario at local and regional levels in order to explore the possible network connection and coherent planning solutions available in a situation. Computational urban development planning is defined in this approach by the structure of the decision-making processes and input-to-output transformational steps rather than just the equipment or mathematical formulas utilized. For these reasons, not all algorithms will be adaptive and not all *computers* are electronic.

Such computational programs can have various origins for different agents, and often different communities will evidence different information strategy behaviors. Economic behavioral algorithms can be largely random where people do whatever money-making opportunities appear, they can imitate the success of others, they can be formulaic and traditional, or they can be experimental and refined with experience. Coward and Salingaros (2004) write that changes in systems like cities are to a large degree the latter with learned through experience hermeneutic strategies organizing output responses to economic input signals and patterns. In order to identify the primary signal inputs, programs, and pattern outputs generated in a region, it is necessary to understand and define the network structure of spatial and communication interactions.

Determining Modules: Network Forms and Structures

Network structuralism theory and methodology focus on patterns of urban relationship *engagement* to capture individual and categorical social and spatial data to measure “exactly who or what is connected, or how” (Neal, 2013, p.3). This allows the collecting of network data of great importance for better understanding urban information exchange and development patterns such as homophily, density, bridging, bonding, and

foci. Neal defines *homophily* as groupings around a similarity. *Density* refers to the degree to which friends of friends are friends with one another (p.21). *Bonding* or strong ties refer to the *closure* of nodes linked together into dense groups. *Bridging* or weak ties support exchanges and interactions between dense groups, sometimes by crossing existing barriers (p. 28-29).

Foci and boundaries combine to structure individuals and spatial interactions and joint activities. Foci can be organizations, places, or events that facilitate relationship (network edge) formation that can form organized clusters from disorganized elements (Neal 2013, p. 34). The focal centers also generate bipartite, or between two type, networks that can reciprocally link individual agents to social, spatial, and commercial *affiliation* networks (Easley & Kleinberg, 2010, p. 84). Common information interests (research questions or technology goals) can also form network foci when spatial or social foci facilitate contact by aiding searching and orienting relative to exploring behaviors (Pan et al. 2013). Initially, the spatial paths and nodes should facilitate other bipartite networks (Salingaros, 1999). Different kinds of contacts and information exchange flow from streets, buildings, open spaces, and other built infrastructure. In this sense, urban space structures program signaling input activity that determines how some agents exchange social information through communication and movement (Salingaros, 2012).

Coward and Salingaros (2004, p. 108) differentiate dense network flows of mutual interaction and signal processing as *modules*. They are determined by the boundaries and webs of greater internal interaction relative to external interactions. A region's economic boundaries are commonly defined by a particular module definition. The US Census Bureau's Municipal Statistical Area or MSA is based on the commuting patterns that link certain residential and employment areas to one another more than to other surrounding areas.

In cities, such modules actually function as interlocking bipartite spatial, social, and business networks. Information can be bounded or diffused by networks across space and between scales, for example from households to neighborhoods to municipalities to regions to national and global markets, depending on the connectivity of networks. In this way, modules can be grouped to form respective network nodes at different levels of

scale. Individuals can be combined into a residential building module. Residential building modules can be grouped to form neighborhood modules that make city or regional modules, and so on. Each module node of a network is itself a network at another lower level of scale in a *nested hierarchy* pattern down to street or building levels (Wicker, 1979). At times the different networks and boundaries within a system can inhibit or promote successful signaling and computing functions horizontally across space and populations and vertically up and down scales. *Semi-permeable boundaries* (including selective network inclusion) function to let certain resources, signals, and populations in while keeping others out, which can create distinct supply and demand distribution patterns in information, resources, or hazards. Analytically, these boundaries' filtering effects can be discernable through distinct distribution patterns within regions. **This can also be designed intentionally to adjust the populations engaged in mutual signaling, distribute and scale spatial foci for particular economic activities, and thus create the modules that compute or perceive development options and outcomes.**

Coordination and Framing System Models

For individuals, understanding the personal computations for certain collective adaptive behaviors are especially important for signal organization, social coordination, and investments. Organizational management theory conceives individuals organizing into groups to address the challenges of dynamic and/or novel environments to improve responses to ongoing change (Maynard et al., 2015). Randall et al. (2011) list three functions, 1) identifying important information, 2) clarifying variable relationships, and 3) framing the systems, standards, and narratives-- as the primary decision-enabling functions of *team adaptation*. **Thus, urban development planning can be structured computationally as networked systems that**

- a) *perceive critical change signals as inputs,*
- b) *organize interaction modules to run strategic programs, and*
- c.) *frame systemic models and narratives to guide decision-making.*

These systemic functions are only adaptive for the whole regional development system if they can serve to process information inputs in an ongoing fashion to support adaptive behaviors throughout the system generally and at each module level.

Table 1: Urban Computational System Elements			
<i>Urban Information</i>	<i>Functions</i>	<i>Metrics</i>	<i>Examples</i>
Module	A processing population unit that incorporates systematic information inputs and distribution pattern signals.	Defined by network graph of interactions between agents, locations, or larger systemic contexts	Neighborhoods Commercial districts Companies or Institutions Commercial industrial sectors Social networks
Program	A process linking response outputs to signal inputs	Defined by routine behavior patterns, tradeoff calculations, systemic contexts, and situational if/then rules	Buy/Sell Cooperate/Defect Imitate/Search
System/model frameworks	Process new signals and change Process linear and nonlinear variable relationships Process (organize) overall system model behaviors and contexts	Defined by overall system contexts: identity narratives, macro organization, assumptions, meaning construction, paradigms, and broad cooperative norms. Large scale investment efforts Collective patterns of exploration activities	Local and regional development standards, norms, and paradigms Development coalitions Planning regimes and narratives Regional reputation

In many U.S. cities, poor social mobility and neighborhood economic equity have sustained inter-generational poverty. These conditions suggest how the potential for competition between imbalanced or opposing populations and their goals within an urban system inhibits planning for mutual, complementary outcomes. The need to change functionality or *adapt* is even harder when a system's modular network structures organize investments against or starve other parts of the system rather than investing in overall system performance on an ongoing basis. As a matter of priority, an urban module

must collectively choose when to maximize its organization for present economic activities or shift to invest in assets to support ongoing flexibility or future productivity improvements. When computing financial capital investments into the structures and performance of physical capital infrastructure these network trade-offs and conflicting goals make it especially difficult to coordinate systemic decision-making. The kind of computations for modeling a system optimum can be defined horizontally across space, vertically in scale, or temporally as returns on investment. However, inputs and outputs will likely change depending on the where, who, or when of an agent's network positions relative to the various models for deploying assets. When such perspectives are shared broadly they can form a common conceptual operating model, paradigm or system. But given important differences in perspective inherent to local social network modules, usually there are competing visions or model frameworks of the overall system states and its constituent opportunities (see Table 1 above).

Given these challenges for computing urban development, what constitutes planning in terms of network *program* functions, interacting population *modules* at different nested hierarchical spatial scales, and normative functionally systemic *model* frameworks and narratives, are all necessary to appropriately define and parameterize. To reiterate, for a computational approach, informational inputs are utilized by agents and modules to determine systematic output response decisions using implicit or explicit *programs*. Agents can calculate programs based upon what they can see, hear, or think for themselves, or they can also tap into social network signaling. An additional level of signal interaction occurs when networked systems form and agents interact with and through markets, media and technology, and governments and institutions.

Regional systems generate the “windows of opportunity” that dictate much of what is possible at subsequently lower scales (Storper, 2011, p. 342). Due to the diversity and complexity of specialized technical knowledge and economic experience needed, locations need sufficient productive expertise in their region, and appropriately organized businesses and social networks to compete within industrial or innovative industries (Hidalgo, 2015). Consequently, regional computations to align the technical expertise and workforce training with adequate physical infrastructure and economic facilities with

social and business networking cooperation and communication are important development planning functions.

CUDP Processing: Collective Synchronization, Intelligence, and Social Signaling

Urban systems function to distribute information, energy, people, waste, and resources. Whether understood as development, sustainability, livability, or resilience, the ongoing system capacity to access and distribute socioeconomic and ecological assets is the primary systemic life support function. At its most basic, this means that the structure of networks must be adequate in relation to situational signals, contexts, timing, and scales. And, the levels of resources, energy, and people, must be adequate. Getting the structure and resources distributions right depends on some process of assessing their current distribution patterns, as well as likely probabilities for beneficial or detrimental patterns or interruptions. After situational data assessment, distributing *synchronizing* signals to coordinate or alter the structure, interactions, and perceptions for additional information processing is necessary to keep the system going. From this highly reductionist perspective, planning urban systems is at base about arranging useful cyclical patterns of networked coordination in time and across space towards recurring systemic function, or, in other words, **urban development planning is in large part the synchronization of network dynamics.**

Nonlinear systems like cities have inherent oscillations and reactions in distributions that are happening all at once, and for this reason, a coherent system must be analyzed all at once as well (Strogatz 2003, p. 182). The more dimensions the system incorporates, the harder it is to perceive, let alone organize in any fashion. Additionally, it is next to impossible to acquire and process timely “global,” macro-level data for an entire region.

Network studies show that some networks can collectively compute useful global patterns if their architecture is organized appropriately. Systems can use local decision rules to solve macro or “global” system problems through networked signal processing and interaction, or *collective computation* (Strogatz, 2003, p. 250-1). Taking design cues from ecosystem and animal synchronization strategies, Pentland (2008) has argued that processes he calls *network intelligence* are the particular form of collective computation

by which humans can successfully synchronize information signaling, network architecture, behavioral norms, and decision-making into complementary patterns. Pentland lists multiple animal strategies (e.g., bees, ants, primates) that support group decisions to maximize rewards and minimize risks. Functionally what is required is a means of gathering and assessing possibilities for group action as well as providing a means by which individuals can know the group consensus. He describes an *idea market* system for network intelligence with these three steps. First, proposed actions and goals are collected as **plans**. Next, everyone in the group signals their personal **interest** in plans based on their personal assessment of relative benefits or costs. Finally, some means of reading a group's overall interest **voting** is computed.

In Pentland's (2008) formula, network intelligence can use both this idea market process of reading a social network to make decisions and predictions about a particular question as well as data analysis tools to read how people sourced their personal information by reading network interaction structures and diffusion. This last measure allows assessment of likely detrimental "group think" scenarios where people are in agreement because they are using a distributed version of the same information source at the expense of divergent signals from alternative sources.

With appropriate network modules to a) collect situational information (inputs), b) communicate diverse plans on how to respond (potential output options), and c) social voting platforms to recruit investments towards implementing these ideas (synchronization), a framework for a network intelligence system for computational urban development planning takes shape. To a certain degree, these network processes of collective cooperation will already exist in many socially open decision-making environments. However, implicit, emotional motivations or "limbic" preference functions related to personal and group interest levels must also be made detectable. "Rational" intelligence functions related to prediction probabilities must be balanced with limbic functions to structurally support individual and collective motivation and information processing structurally. Through the network dynamics of urban design, modules can passively support the interaction and signaling of intentions and interest relative to commercial signals simply by focusing people's attention towards individual-to-group

social voting computations on emerging economic patterns and potentials such that adaptation and development planning can become systematized throughout a region.

Page et al. (2003) developed a *network-oriented development* concept designed to enhance “the right strategic investments in technology, social and political networks, and ultimately physical space.” Their Network Station concept advocates a local neighborhood-level facility to support local development activities that can increase the mix of functions supportive of economic adaptation from skills training, retail, business incubation, social services, as well as technology and innovation access. Were data from such facilities harnessed and collated into idea market formats at multiple regional scales, the economic development network intelligence capacities of localities could be much enhanced by improving social signaling, risk/reward assessment, and linked to investment streams to pay for them (See Supplemental 2).

CUDP Procedural Framework

As an initial exploration of an integrated computational urban development planning approach, a list of analytical steps is introduced below. These are provided as theoretical examples to support further research, modeling, and validation efforts, not as comprehensive policy recommendations. Furthermore, it is important to acknowledge the limitation that innovation-focused regional economies must foster development activities which are both politically complicated and dynamically complex. The realities of jurisdictions, egos, and personal agendas are not addressed. While the effort to organize information and resources to structure broad-brush population behaviors is central, the private and personal agency, psychology, and behaviors of individual participation are barely addressed. Augmenting collective capacities for innovative development via spatial, social, financial, and other network adjustments has inherent social engineering dangers and democratic challenges. Incorporating the private sector’s competitive imperatives as a whole are not directly addressed here either. Conceptually, it is simpler to identify barriers to synchronization, connection, or market exploration in an area using network tools than it is to formulate appropriate network bonding, bridging, data, foci, or entrepreneurial activity enhancements that require public and private cooperation and investment. However, the effort to openly and democratically explore the potential for

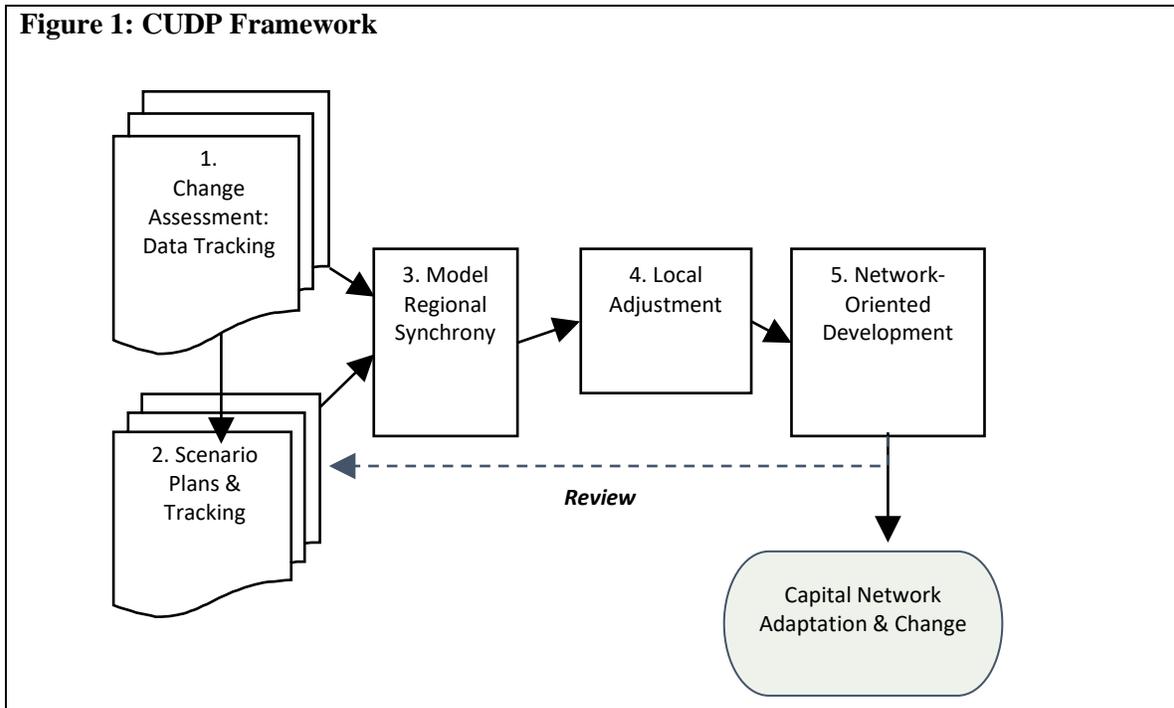
mutual benefit and enhanced regional performance might be rewarded with new policy prototypes and community collaborations.

It is also important to note that different kinds of economies will be computing different kinds of network enhancements due to functional differences in local economic limitations. Factor-based competitive advantages in a region can be defined primarily as a network **distribution**-focused exchange patterns, concerned with supply and demand relationships across and between regions. Efficiency-based competitive advantages in productivity, quality, and lower costs over a region can be defined as optimizing network **coordination**-focused dynamics, where predictability, controls, and transaction costs drive the refinement of distribution. The innovative creation of new business models, technologies, products, services, and firms within a region can be defined as a network **generation** problem, as new competitive advantages, efficiencies, and market demand must be created by local economic agents.

Due to the speed of change and the scales of interactions, long-term prediction is extremely difficult in a global economy. As a result, development planning is better oriented towards adaptive capabilities and structural shifts to repair network problems and organize new business explorations, rather than guessing the future. Planning for regional economic development can thus benefit from network science tools, but in different ways depending on the situations, goals, and trajectories of regional networks being analyzed. Most importantly, from a computational perspective, the planning algorithms related to improving distribution, coordination, and generation must enhance network function overall rather than investing in one aspect to the detriment of others. Each network function should complement, not dominate others.

The relative balance will be different depending on the scale of analysis. Because the bulk of new business strategies and associated firms start small initially, a) network generation algorithms should address smaller, local network (module) interactions and functions. If we are interested in scaling these companies we need to know that critical resources are accessible, so b) network distribution algorithms must be able to compare an entire regional MSA (module) aggregate “big picture.” In order to synchronize larger and smaller scales' spatial distributions, densities, and flows, c) network coordinating algorithms must manage data gathering, signaling, scaling, through social and spatial

networks. The algorithms from Christopher Alexander's (2005, p. 4) *Fundamental Process* partially inspires the framework progression, and specific computational algorithms to further demonstrate these procedures are listed in Supplemental 1.



The process attempts to coordinate planning relative to longer-term market shifts and systemic change for important regional production networks (see Figure 1 above):

1. **Identify** quantitative changes in supply and demand that indicate systemic capital obsolescence.
2. **Simulate** several scenarios of potential qualitative market shifts, and establish plans.
3. Adjust regional parameters to match **industry, infrastructure, & workforce** investments to plans
4. Balance and stabilize capital appreciating and depreciating cycles, concentration, segregation, and bottlenecks at community module scales.
5. Implement network-oriented development: Communicate to region what is new and next to innovate? What business sector shifts are needed? Where?

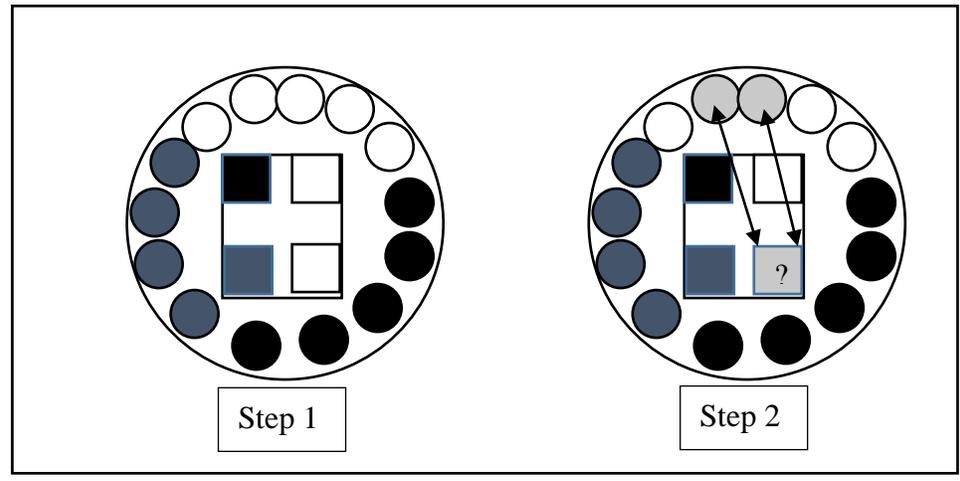
Step 1: Data Tracking

At the regional level, the most important econometric data to gather and track include sales patterns for products and services related to the largest regional employment sectors. Indicators in wages, employment, and housing values can lag too long for timely planning responses. However, an innovative new *product network* analytical approach has been developed to quickly predict changes in sales based on correlated products with similar sales patterns (Dhar et al., 2014). The main requirement is that data be identified, compiled, and tracked, so that regional employment situations and market sectors, or what Hausmann et al. (2013) called *product space* can be assessed in the aggregate and with as much spatial precision as possible. Regional products have associated building and employee geographic patterns. When these networks are geocoded relative to unemployment, vacant sites, and building permit investment data, the module shifts become more detectable. Using these kinds of data with sales numbers allows regional planners to better anticipate the impacts in employment and wages. If product and service sales are declining or shifting geographically, new supplies of appropriately skilled employment of sufficient wages of sufficient scale will be needed.

For example, many mining communities have been affected by declines in the US coal industry as fracking creates cheaper supplies of natural gas. It has also affected regions that do not mine coal, but whose economy was connected in other ways, such as transport. Recently, Roanoke, Virginia lost many railroad jobs as electrical company demand has dropped. Appropriate regional analytics should focus on such supply and demand shifts for key companies and their customers so that regional planners can better predict the potential for large-scale employment and infrastructure usage disruptions before corporate announcements. With this knowledge, integrated plans to shift workforce, infrastructure, and product development investments towards potential replacements are tested and scaled as quickly as possible.

In Figure 2 (below), an urban center (large circle) includes worker populations (small circles) and buildings/infrastructure (squares) associated with different product sectors (shading). Market trends indicating capital obsolescence like unemployed workers and vacant sites (white) trigger coordinated planning to adapt market sectors, workers, and sites.

Figure 2. As adaptive cycles result in lost jobs (circles), industries (circle shading), and building tenants (squares), new economic uses (grey) are experimentally targeted at levels appropriate to calculated need. In step 2, new products are matched to open populations and sites.



Step 2: Planning Scenarios and Simulations

When a new regional development plan makes certain predictive assumptions, those can be described and quantified as specific network metrics within a model that can act as hypotheses for ongoing testing. Over time, data tracking of predicted variables, like product sales or new employment, must be measured against actual metrics. Over time this planning, modeling, tracking, and remodeling acts as a policy *corrective feedback* (negative feedback) to adaptively guide regional planning and coordination towards systemic goals. By integrating both scenario planning and heuristics towards ongoing performance enhancement, a system can get better at both prediction and validation as it learns (Allen 2014). In order to heuristically guide regional development, predictive network scenario planning models and simulations must anticipate employment, institution, and infrastructure targets and acceptable variances statistically as well as spatially (see Step 2, Figure 2 above).

By tracking regional economic data, scenario predictions, and results longitudinally, a regional planning system can improve overall modeling and adaptive response speeds. When data exceed model variance thresholds, it triggers new rounds of regional modeling and planning to improve responsive coordination of investment and

policy. Unknowns mean planners can only manage investments and policies on the basis of probabilities (Batty and Marshall, 2012). However, they are positioned to adapt rapidly if data inputs and associated probabilities are constantly updated and compared over time.

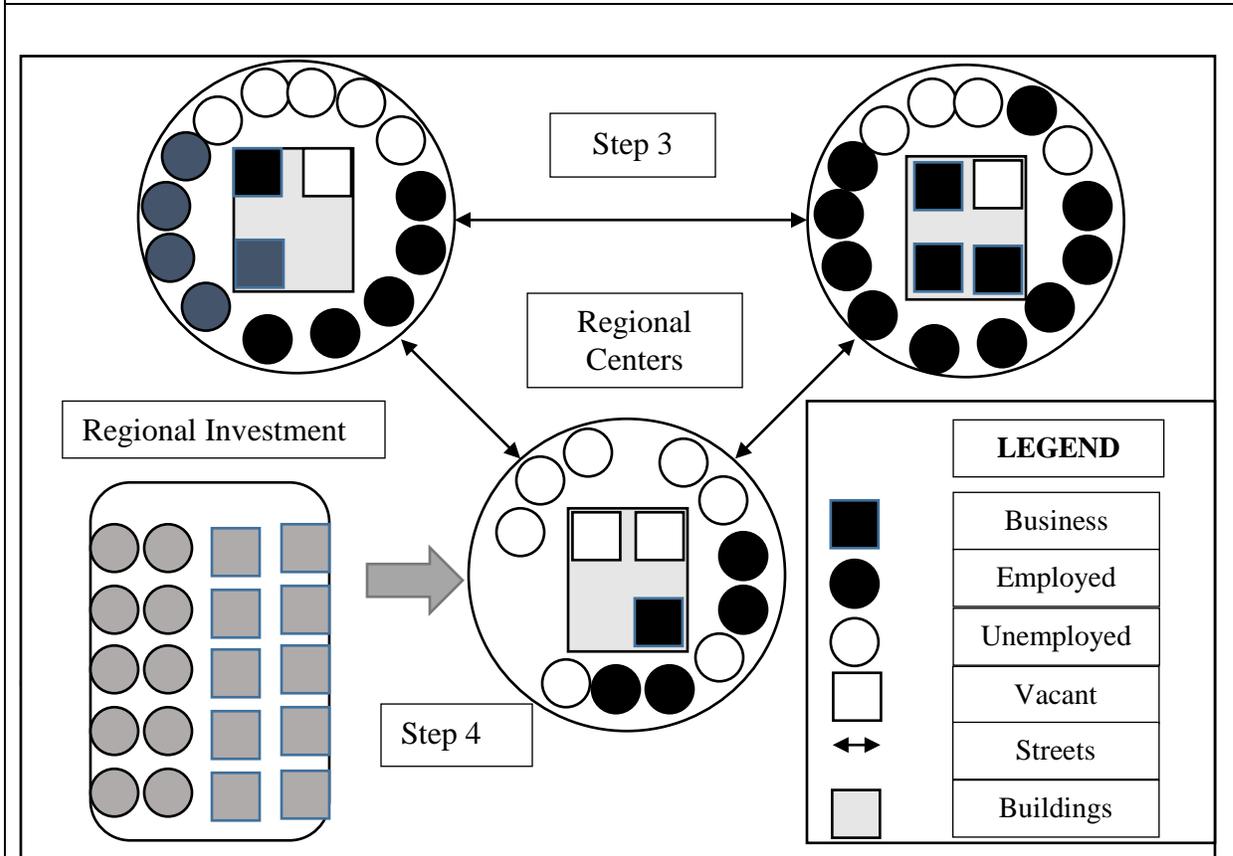
Step 3: Synchronizing Regional Capital Networks

Overall regional supplies of assets are stored somewhere within the smaller scales where people work and shop. Functional community modules organize the larger regional aggregation and distribution patterns. Strong neighborhoods can concentrate economic assets that support development generating activities like sales, employment, training, research, and cultural production. So the main commercial and developable buildings and streets should have their spatial, social, and financial networks analyzed and geocoded for regional comparison and aggregation (scaling). For each of these local nodes of development, the boundaries of local investment, commercial activities, social modules, street life, as well as any network-oriented development capacities should be assessed and tracked (see Figure 3, Step 3).

Step 4: Synchronizing Local Module Networks

Network models of urban development spatial and social regional distribution patterns in employment, infrastructure, and industry sectors can guide extremely fine-grained planning at both systemic and local scales to support greater synchrony. Step 2 examines economic change over time, and step 3 conducts network analysis to explore regional employment, building vacancies, and business revenues overall. Step 4 adjusts spatial distributions to different urban communities within a region. A region may need a larger supply of certain buildings, workers, or information gathering sites, institutions, or groups to support regional development into new products and services, but those supplies are constructed and positioned in particular areas by particular agents, often in the private sector. Additionally, individual firms and building developers may benefit (capture rents) by keeping the supply of workers and buildings artificially low through the practice of *opportunity hoarding* within a preferred social network (Tilly, 1998, p.10). So it is critical to understand where capital is underutilized to target the exploration of emerging economic opportunities.

Figure 3: Step 3 identifies and graphs regional development patterns between urban centers in a region. Step 4 targets regional investments towards adapting assets to limit excessive concentrations and stagnation.

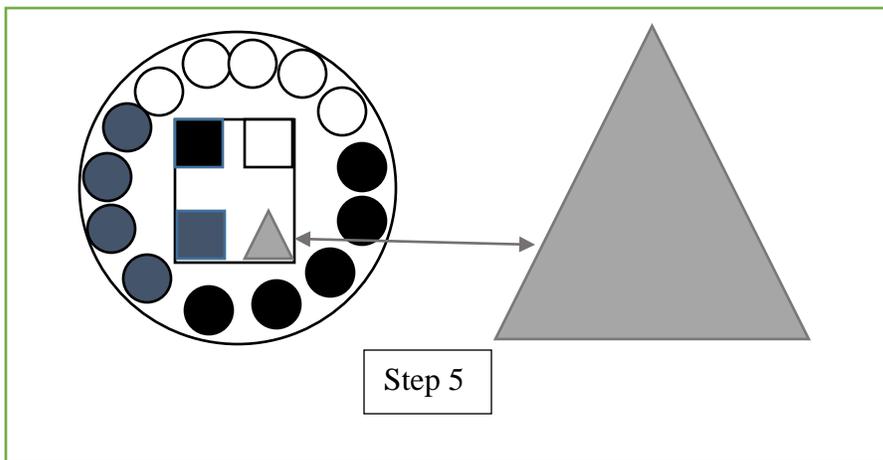


With a network graph of local neighborhood centers and land use nested within regional graphs and maps of economic activity, it is possible to plan adaptation in a coordinated system. Embedded nodes can report local patterns with regional data tracking, aggregate individual's human development efforts, communicate investment incentives, and update resulting changes. Key sets of planning computations should monitor these investment levels in different locations to better adjust regional supply towards strong *opportunity synchronization* with planning goals for stable and adequate supplies and costs for labor, facilities, and information exchange platforms (see Figure 3, Step 4 above).

Step 5: Network-oriented Development of Regional Information Systems

In addition to sales and employment patterns resulting from existing business types, new entrepreneurial business models and innovative products and services signal key areas of future development. They are also the main adaptive activities in a region, as commercialization efforts and experimental targeting of new markets and customers can remedy skill and capital asset obsolescence. For local areas which need far more new businesses and employment opportunities, site foci devoted to gathering and supporting entrepreneurial teams and individuals are the remedy. By exploring new skills, strategies, and products in such experimental spaces such as co-working sites, maker spaces, business incubators, and technology “home brewing” clubs, new careers and companies are born. These experiments produce and refine the mental models that form the basis of emerging forms of expertise and human capital. If the experimental targeting activities are sufficiently affiliated with neighborhood sites and populations (see Chapter 4), the business and social network engagement can scale (see Figure 4). An assessment of network signaling with other such entrepreneurial nodes in the region can also be studied to identify network engagement and spatial gaps in need of bridging over the region at large as well as to a given neighborhood.

Figure 4: Network-oriented development: local adaptive sites (small triangle) and activities link to overall adaptive network activity for sites, populations, and development plans at regional levels (large triangle).



Because of the consistent, emotional, and contextually supportive quality of face-to-face interactions, this network planning computation functionality is best integrated into local community *foci* hubs throughout a region. Previously these were described as

nested hierarchical networks of urban centers, land use, and population building affiliations. Computational urban development planning regional synchronization is structured to support the coordination of individual decisions relative to regional business or employment opportunities and plans. These functions occur through networks of activity coordination and networks of perception and discovery at multiple levels (see Chapter 4). Individual economic decisions and behaviors are typically performed in the context of locally situated commercial, spatial, and social networks in particular urban sites. Computing collective investment and activity coordination decisions regionally, and monitoring local investment and interaction activity can harness network analytics towards ongoing economic adaptation in a region.

Summary

Network-oriented development is but one example of planning interventions suitable for synchronizing capital to support computational development network capacities over time. Network interventions in specific locations must take note of module structures, local social behaviors related to decision-making, and the current regional economic planning structures. Where there are gaps in the needed links between and among neighborhood modules they must be better bonded or bridged (Neal, 2015). Where the behavior rules or risks for economic cooperation are weak in particular areas, a platform by which people can make information and resource transactions with a more reliable central system rather than unreliable neighbors, should lower transaction costs and increase collaborative information-sharing.

Where extensive economic development activity information and signaling is not being collected and integrated categorically and spatially at the regional level, such model information platforms should be constructed. Currently, a significant limitation exists due to individual and business privacy concerns which make much data difficult to collect efficiently and affordably. It is possible to use statistically simulated populations to circumvent this issue for modeling. Regardless, public network data gathering will become increasingly necessary if regions are to organize and synchronize workforces, entrepreneurship, physical facilities, transportation, education, and retail activity and investment towards providing adequately scaled economic opportunities relative to local,

urban, regional and global market stresses and risks. Privacy and control parameters will have to be appropriately designed to function democratically. This is a point of critical importance for ongoing research efforts.

Network intelligence tools can be used by and for the benefit of those whose signaling data is being aggregated as a deepening of adaptive democratic capacity. They can also be used to manipulate populations, skew results, and co-opt public resources. The safeguards and performance measures for such systems should be far more advanced before such a system can responsibly be used for regional governance. Research towards these protections is a critical priority for emerging computational planning and collective intelligence approaches.

The objective here was to conceptualize approaches to model, coordinate, and plan urban development opportunities and capabilities computationally. Contemporary economic development--particularly for innovation-driven development--requires information systems that empower the identification and generation of economic opportunity at scales from regions to communities to individuals. This is not so different than the processes by which initial factor-driven economies first come into being. Someone somewhere recognizes a value adding situation and they are able to organize a business around it. If that business model is copied and expanded, then the local physical and social networks organize around those businesses in turn. But a time comes when business, social, or spatial networks need to change, however. The rapid recognition of pending regional economic obsolescence in lockstep with the redistribution of networks and associated capital towards emerging attractive opportunities facilitates expanding economic transformation throughout the system. In this way, many of the development and planning challenges can be understood and capital adjustments computed (see Table 2).

Such development systems can break down when they are not monitoring critical economic internal and global flows for unexpected or ongoing decline. New network tools to predict economic network behavior can facilitate such data gathering. Development can break down when certain social classes and cultural practices hoard assets at the expense of those less integrated into economic networks. In short, regional economic systems can break down when not synchronized: when the times for new

discoveries, teams, and investments are not observed, articulated, communicated, incentivized, scaled, and organized with appropriate facilities, infrastructure, services, leadership, and technology. Networks function to support scaling, engagement, and coordinated perception for economic development (see Chapter 3).

Table 2: Regional development planning					
<i>Development Challenges</i>	<i>Spaces</i>	<i>Networks</i>	<i>Capital</i>	<i>Outputs</i>	<i>Planning Challenges</i>
Bounded distributions	Geographic space	Transportation networks	Physical capital	Scale & structure	Prioritize placemaking
Bounded cooperation	Cultural Space	Social networks	Social capital	Engagement & investment	Synchronize capital
Bounded rationality	Technical Space	Information networks	Knowledge & human capital	Expertise & models	Network intelligence
Market supply & demand change	Product Space	Product networks	Financial capital	Value & wealth	Network-oriented Development

Specific network forms guide these processes (see Chapter 4). *Networks of centers* integrate local urban development nodes together into a regional framework. Even with regional support, the local community *activity coordination networks* must synchronize development activities among urban streets and buildings as the key interface between people and development. Economic activity is a fundamental organizing signal for urban populations, so the *networks of land use* organize urban site development. Even with global markets and ever higher forms of technology to dilute the signal importance of public economic urban space, face-to-face contact is still the basis of social *networks of cooperation* construction. This social fabric is essential for social organization, collaboration, and other development network forms and computations. This will be true as long as businesses need suppliers and customers, and people need economic experience and contacts. But the *networks of perception and discovery* are the means by which change is detected, options and experiments are explored, and

opportunities are found. CUDP attempts to regionalize and systematize these network forms and functions for economic development.

Data are not as simple to gather, nor is public cooperation in the face of change. Situational awareness of a regional system calls for a means of detecting signals, sharing intentions, and communicating subsequent patterns. Timely and accurate data signals and appropriately structured data analysis methods support successful urban development planning. Missing, unstructured, or lagging input data streams confuse and disempower a system's capacity to appropriately match network structures and decision dynamics (e.g. behaviors, programs, feedbacks, etc.) to desirable output computation. In this sense, network data are the ultimate base of adaptive feedback loops. Developing regions starts with developing this data.

But research efforts do not have to begin at a regional scale. The important thing is to begin somewhere. Any development efforts to enhance economic activity and lower costs for opportunity searches improve the likelihood of both individual and collective improvement. Future research could include a simpler but scalable demonstration of these principles that simulates a particular region. Clearly, many studies of various component elements of computational urban development planning are now extant. However, an overall model framework to communicate change and scale investments has only been outlined here. Computational regional model prototyping remains an important research agenda for urban development theory and practice so that it can be sufficiently studied to understand the risks, rewards, and limitations entailed.

References

- Acs, Z. J., Desai, S., & Hessels, J. (2008). Entrepreneurship, economic development and institutions. *Small Business Economics*, 31(3), 219–234.
- Alexander, C., & Center for Environmental Structure. (2005). *A vision of a living world: Nature of Order, Book 3*. London: Taylor & Francis.
- Allen, P. M. (2014). Evolution: Complexity, uncertainty and innovation. *Journal of Evolutionary Economics*, 24(2), 265-289. doi:10.1007/s00191-014-0340-1
- Batty, M., & Marshall, S. (2012). The Origins of Complexity Theory in Cities and Planning. In J. Portugali, Meyer, H., Stolk, E., and Tan, E. (Editors) *Complexity Theories of Cities Have Come of Age: An overview with implications to urban planning and design*. New York: Springer: 24-47.
- Coward, L., & Salinger, N. (2004). The information architecture of cities. *Journal of Information Science*, 30(2), 107-118.
- Dhar, V., Geva, T., Oestreicher-Singer, G., & Sundararajan, A. (2014). Prediction in economic networks. *Information Systems Research*, 25(2), 264-284. doi:10.1287/isre.2013.0510
- Easley, D., & Kleinberg, J. (2010). *Networks, crowds, and markets: Reasoning about a highly connected world*. New York: Cambridge University Press.
- Hausmann, R., Hidalgo, C., Bustos, S., Coscia, M., Chung, S., Jimenez, J., Simoes, A., & Yildirim, M. (2013). *The atlas of economic complexity: Mapping paths to prosperity*. US: MIT Press.
- Hidalgo, C. A. (2015). *Why information grows: The evolution of order, from atoms to economies*. New York: Basic Books.
- Holland, J. H. (2012). *Signals and boundaries: Building blocks for complex adaptive systems*. Cambridge, Mass: MIT Press.
- Huggins, R., & Thompson, P. (2015). Entrepreneurship, innovation and regional growth: A network theory. *Small Business Economics*, 45(1).
- Johnson, T. G. (2009). Targeting with the analytic hierarchy process. In Goetz, S., Deller, S., and Harris, T. (Editors) *Targeting Regional Economic Development*. New York: Routledge: 241-253.
- Kegan, R., & Lahey, L. L. (2009). *Immunity to change: How to overcome it and unlock potential in yourself and your organization*. Boston, Mass: Harvard Business Press.
- Maynard, M. T., Kennedy, D. M., & Sommer, S. A. (2015). Team adaptation: A fifteen-year synthesis (1998-2013) and framework for how this literature needs to "adapt" going forward. *European Journal of Work and Organizational Psychology*, 24(5), 652-26. doi:10.1080/1359432X.2014.1001376
- Neal, Z. P. (2013). *The connected city: How networks are shaping the modern metropolis*. GB: Routledge Ltd. doi:10.4324/9780203101728.

- Neal, Z.P. (2015). "Making Big Communities Small: Using Network Science to Understand the Ecological and Behavioral Requirements for Community Social Capital." *American Journal of Community Psychology* 55.3: 369-80.
- Nowak, M. A., with Highfield, R. (2011). *SuperCooperators: Altruism, evolution, and why we need each other to succeed*. New York: Free Press.
- Ortman, S. G., Cabaniss, A. H. F., Sturm, J. O., & Bettencourt, L. M. A. (2015). Settlement scaling and increasing returns in an ancient society. *Science Advances*, 1(1), e1400066-e1400066. doi:10.1126/sciadv.1400066
- Page, S., Phillips, B., & Siembab, W. (2003). The millennium city: Making sprawl smart through network-oriented development. *Journal of Urban Technology*, 10(3), 63-84. doi:10.1080/1063073032000175417
- Pan, W., Ghoshal, G., Krumme, C., Cebrian, M., & Pentland, A. (2013). Urban characteristics attributable to density-driven tie formation. *Nature Communications*, 4, 1961.
- Pentland, A. (2008). *Honest signals: How they shape our world*. Cambridge, Mass: MIT Press.
- Randall, K. R., Resick, C. J., & DeChurch, L. A. (2011). Building team adaptive capacity: The roles of sensegiving and team composition. *The Journal of Applied Psychology*, 96(3), 525-540. doi:10.1037/a0022622
- Rubin, H. J. (1988). Shoot Anything that Flies; Claim Anything that Falls: Conversations with Economic Development Practitioners. *Economic Development Quarterly*, 2(3), 236–251.
- Salingeros, N. A. (1999). Urban space and its information field. *Journal of Urban Design*, 4(1), 29-49. doi:10.1080/13574809908724437
- Salingeros, N. A. (2012). Urbanism as Computation. In J. Portugali, Meyer, H., Stolk, E., and Tan, E. (Editors) *Complexity Theories of Cities Have Come of Age: An overview with implications to urban planning and design*. New York: Springer: 247–270.
- Simmie, J., and R. Martin. (2010). "The Economic Resilience of Regions: Towards an Evolutionary Approach." *Cambridge Journal of Regions Economy and Society* 3 (1): pp. 27–43.
- Simon, H. A. (1991). Bounded rationality and organizational learning. *Organization Science*, 2(1), 125-134. doi:10.1287/orsc.2.1.125
- Solow, Robert (1957). Technical change and the aggregate production function. *Review of Economics and Statistics* 39 (3): 312–320.
- Storper, M. (2011). Why do regions develop and change? The challenge for geography and economics. *Journal of Economic Geography*, 11(2), 333-346. doi:10.1093/jeg/lbq033
- Storper, M. (2013). *Keys to the city: How economics, institutions, social interactions, and politics shape development*. Princeton, NJ: Princeton Univ. Press.

- Strogatz, S. H. (2003). *Sync: The emerging science of spontaneous order*. New York: Hyperion.
- Tilly, C. (1998). *Durable inequality*. Berkeley, Calif: University of California Press.
doi:10.1525/j.ctt1ppftj
- Wicker, A.W. (1979). Introduction. In *Behavior settings: An introduction to ecological psychology*. Monterey, CA: Brooks/Cole: 1-25.

Supplemental 1: Sample Urban Development Computation Algorithms

The steps and framework from Figure 1 in Chapter 6 describe qualitative categories suitable for conceptualizing the approach. However, mathematical simulation models need more direct decision parameter descriptions. Below are suggested data sources, data analysis methodological references, and planning algorithms to clarify how a prototype regional model of an MSA might be initially organized.

Sample Model Algorithms
<p>1. Economic Product Network Prediction Computation</p> <p><i>Source: Dhar, Geva, Oestreicher-Singer, & Sundararajan (2014)</i></p> <p>Data: Select product networks and sales pattern tracking data by graphing links formed when two products are often purchased together. Seek to predict future demand for individual products through <i>patterns in the aggregated product network local clustering coefficient and global centrality properties</i> (e.g., based on attention levels scored by Amazon PageRank).</p> <p>If product network predictions indicate substantial loss of demand in regional products and associated employment;</p> <p>Then create new multi-level development plans (see below) including modeling sales and employment projections.</p>
<p>2. General Planning/Modeling Computation</p> <p><i>Source: Allen (2014)</i></p> <p>Data: Select a development plan and act on it; compare planning model assumptions to economic reality (see Prediction Computation above);</p> <p>If unexpected deviations and new phenomena identified;</p> <p>Then revise plans and models to explore a new range of possible futures.</p>
<p>3. Regional Capital Development Computations</p> <p><i>Source: Schrock (2014)</i></p> <p>Data: Select regional data on public and private investments in economic skills, business and social networks, and local career dynamics relative to Prediction and Planning Computations (above)</p> <p>If stable; then try to improve balance spatially and demographically to promote equitable</p>

prosperity throughout a region's locations.

If development human capital, network capital, and physical capital are unstable or declining:

Then improve lagging capital formation:

If human capital lagging; then plan skill development: a. define what incentive and motivation for investments, b. define who invests

If network capital lagging; then plan employment networks: A. define a process of worker-employer connection (matching, searching, recruiting dynamics), b. define labor size projections, c. define specific skill projections (see also Supplemental 2)

If physical capital inadequate; then plan local physical site enhancement to support social economic integration goals (see below)

4. Social-Spatial Community Module Development Computations

Source: Neal (2015)

Data: Select regional physical site and social network data in order to define community interaction *modules, network behavior programs, and community cultural model contexts*. Use network tools to identify setting and behavioral requirements of community social capital: including within group *bonding* & between group *bridging* graphs and behaviors as indicated by:

- a. Clustering—within group relations—contacts' friends of friends with each other
- b. Average path length or network distance—between-group ability to rapidly and efficiently share information and resources—direct or indirect opportunities for interaction

If bonding metrics like clustering and socioeconomic homophily indicates excessive community insularity that may be resistant to economic change as well as monopolizing internal relationship cultivation at the potential expense of resident's access and ability to interact with other communities' resources (capital) via bridging relationships;

Then create, improve, design, and invest in bridging urban gathering sites and activities (See also Planning Computation above for urban designs).

If bridging metrics like network distance or node degree indicate a community is not organizing (bonding) around shared development goals;

Then create, improve, design, and invest in development teaming activities (see below).

*Note: Focus must be on creating the potential for development. How easy is it to find contacts locally?

**Note: Increasing *connectivity* not yet creating a system of incentives for development (Andris and Bettencourt 2014).

5. Team Adaptation Computation

Source: Randall, Resick, and DeChurch (2011)

Data: Select and gather demographic and behavioral data (behavior groups) at significant economic activity sites (behavior settings), relative to business and social network generating activities in the form of team adaptation behaviors (particularly collective orienting/aligning/organizing; connection opportunity searching; and knowledge exploring relative to business development.

If behavior setting, behavior groups; or development behaviors are lacking, inadequate, or limiting these variables coevolution;

Then:

Develop Behavior Sites: “experimental spaces” (Brand 1994, p. 24): flexible or large working environments full of microenvironments each a different creative space; low rent, high turnover, no-design; temporary, improvisational spaces;

Develop Networks of Adaptive Behavior: Sense-making—scanning the environment for important changes and reconstructing meaning around those changes (Adapt local Prediction Network into forms of idea markets). Sense-giving—structuring of knowledge in the form of similar and accurate mental models (adapt General Planning Computation above to local information contextual dynamics).

6. Reset Computation

Data: Convert output data from each computation to regional and distributed network hubs to support input data gathering, modeling, adaptation, and activity organization at every level and the creation of idea markets and iterative network communication.

References

- Allen, P. M. (2014). Evolution: Complexity, uncertainty and innovation. *Journal of Evolutionary Economics*, 24(2), 265-289. doi:10.1007/s00191-014-0340-1
- Andris, C., & Bettencourt, L. (2014). Development, information and social connectivity in Côte D'Ivoire. *Infrastructure Complexity*, 1(1), 1-1. doi:10.1186/s40551-014-0001-4
- Brand, S. (1994). *How Buildings Learn: What happens after they're built*. New York, NY: Viking.
- Dhar, V., Geva, T., Oestreicher-Singer, G., & Sundararajan, A. (2014). Prediction in economic networks. *Information Systems Research*, 25(2), 264-284. doi:10.1287/isre.2013.0510
- Neal, Z.P. (2015). "Making Big Communities Small: Using Network Science to Understand the Ecological and Behavioral Requirements for Community Social Capital." *American Journal of Community Psychology* 55.3: 369-80.
- Randall, K. R., Resick, C. J., & DeChurch, L. A. (2011). Building team adaptive capacity: The roles of sensegiving and team composition. *The Journal of Applied Psychology*, 96(3), 525-540. doi:10.1037/a0022622
- Schrock, G. (2014). Connecting people and place prosperity: Workforce development and urban planning in scholarship and practice. *Journal of Planning Literature*, 29(3), 257-271. doi:10.1177/0885412214538834

Supplemental 2: Case Examples of Employment Matching and Idea Market Network-oriented Development Dynamics

The way neighborhood modules might function to connect individuals to a regional development system was very briefly theorized in the chapter, however, there are existing systems which demonstrate many of the development network processes within these modules. Firstly, the Charlottesville Works Initiative is a program that attempts to connect employers, employees, and resources towards regional development priorities. Next, an existing idea markets for business development is introduced, followed by summaries of career matching with contract systems utilized by military and medical educational institutions. Network and market-based procedures like this can be studied towards adapting new business and workforce development planning and funding strategies from working models. The structures and processes described can be key components within larger, integrated regional synchronization efforts.

Charlottesville Works Initiative: Regional Employment Network Repair

Although the concepts described in the paper are largely theoretical, there are a number of efforts which demonstrate existing practical applications. As an example of an existing effort to utilize network tools for development in one central Virginia location, the Charlottesville Works Initiative, grew out of an effort to locate community spatial concentrations of low-income families. The Orange Dot Project as it was called, identified 5,661 families in the region, about 18 percent, whose household income was inadequate for financial self-sufficient income (Schuyler, 2015, p.8). They then developed a model set of programs to “design a more intentional system for identifying people being left behind in our economy and connecting them to the quality jobs and supports in our community” (Schuyler, 2015, p.16). The model is organized around 8 network development aspects:

1. Jobs identification--employer and community networks contacted to identify jobs,

2. Job information--“actionable intelligence” concerning requirements and benefits gathered from employers,
3. Job candidate identification—peer/social networks deployed to identify jobs seekers by identifying individuals and programs with direct and trusted contacts with target populations,
4. Peer/community networks—peer contacts are trained on protocols to identify suitable job candidates for available jobs, candidate support needs, and how to coordinate the support.
5. Ongoing support—skill training, life management, and healthcare service needs that were identified for job candidates must be bundled for the first few months or year of employment,
6. Resources—community skill, life management, and healthcare service provider investment and capacity building,
7. Coordination—resources must be matched to job candidate support needs
8. Quality control—validation that individuals completing the process are exiting adequately prepared for work, and that the program is doing an adequate job of assisting people to get and retain employment (Schuyler, 2015, p.19-23).

These information acquisition and system coordination programs attempt to serve as a “seamless pipeline” between disconnected populations and jobs. These efforts have also explored partnering with spatial community hubs, as well as entrepreneurial training and business ownership support programs (Ingles, 2013). As of late 2015, Of the 17 people that have completed training 15 were employed with the vast majority making more than \$25,000 a year (Schuyler, 2015, p. 17).

With needy families in the area numbering in the thousands, the task of scaling this model informationally and financially is a tremendous task. The processes can be understood as spatially mapping and graphing populations and networks that serve as workforce interaction modules, including peer/social networks, employer networks, and human services groups. The programs discussed above list the network inputs, signaling structure, and desired outputs within the initiative’s model framework. As these processes progress, additional system enhancements to help different networks better coordinate resources with needs and opportunities over time are likely to improve the overall

regional understanding of employment dynamics and economic situational awareness of poverty and latent capacities relative to opportunities.

This regional-scale emerging picture can enable development teams to adapt more quickly and with fewer wasted resources. Additionally, development programs relative to underused physical capital inventories and improvement activities for community streets and buildings, as well as econometric prediction tools to identify potential major workforce layoffs or hiring growth could further enhance network coordination and capital allocation decisions. These programs could also support larger regional efforts to scale the program if successes motivated, informed, and coordinated more individuals as participants in the various networks and groups.

Networks, Markets, Matching, and Urban Informatics

A decade ago, an influential *New York Times* article introduced a defense contractor's use of an *idea market* model to develop products and services within the company by changing the "architecture of participation" The company allows any employee from executives to receptionists to propose efficiencies, acquiring technologies, or entering new business sectors which become stocks with their own symbols, discussion boards, and email alerts. Employees then buy or sell stocks to reflect their interests (Taylor, 2006). While not face-to-face, the network exchanges of personal interest information relative to an open proposal platform was successful in a product that eventually generated 30 percent of the company's income.

Aside from the potential for larger companies in search of better internal innovation platforms, the last ten years has seen a dramatic increase in crowdsourcing and crowdfunding platforms for both business and social entrepreneurs (Hossain, 2015). To date, however, few if any localities have used such idea markets to match ideas, resources, and support networks for entrepreneurs and recruiting within specific industries, services, or locations. The conditions under which markets best support crowdsourced knowledge-sharing is an ongoing topic of research (see Maciejovsky and Budescu, 2013). But, many communities find themselves in need of additional adaptive inputs that could well profit from scaling and engaging the knowledge-sharing and relationship-generating power of such a platform.

As regards workforce adaptation and sorting platforms, each year military and medical student graduates bid on respective branch/base and hospital assignments. For example, cadet graduates of the United States Military Academy are sorted by an order-of-merit list and service branch preferences (e.g. infantry, aviation, etc.) relative to the number of positions each branch requests. Since 2006, Cadets have had the option of increasing their years of service obligations in exchange for improving their chance to get into a more desirable branch (Sönmez, 2014). This form of modified workforce supply and demand system or *matching with contracts* model (Hatfield and Milgrom, 2005) is one potential method by which large-scale regional employers and smaller enterprises that compete for employees in specific skilled trades could collaborate with regional training institutions to better synchronize employers, employees, and workforce investments. Institutions could pay towards specific training in exchange for priority matching privileges. Students could contract to fill the employers' priority quotas according to market matching rules in exchange for scholarships and financial aid. Regional workforce training institutions could calibrate the training pipeline to employer bids as well as predictive econometrics based on shifts in local product sales and employer market share shifts as well.

As these models suggest, using certain network-oriented information collection and exchange platforms to guide investment and organizing are not entirely new, untested, or without successes in certain contexts. What is novel would be their application towards systematic and integrated local-to-regional business and workforce processes. Community preference and prioritization platforms for targeting economic development like the *analytical hierarchy procedure* have been around for decades as well (Johnson, 2009). However, instead of focusing on identifying industries to recruit, markets can identify resources and people to generate targeted coordination of skills and businesses from within a region. What computational tools offer is the potential to harness these tools and models together to guide individual and group decision-making for an age of ongoing global innovation.

References

- Hatfield, J. W., & Milgrom, P. R. (2005). Matching with contracts. *The American Economic Review*, 95(4), 913-935. doi:10.1257/0002828054825466
- Hossain, M. (2015). Crowdsourcing in business and management disciplines: An integrative literature review. *Journal of Global Entrepreneurship Research*, 5(1), 1-19. doi:10.1186/s40497-015-0039-2
- Ingles, L. (2013, Sept. 3). Can social entrepreneurs close the local income gap? Toan Nguyen thinks so. *Cville Weekly*, 25(36), 16-20. <<http://www.c-ville.com/can-social-entrepreneurs-close-the-local-income-gap-toan-nguyen-thinks-so/#.VuxsoXrqWI4>>
- Johnson, T. G. (2009). Targeting with the analytic hierarchy process. In Goetz, S., Deller, S., and Harris, T. (Editors) *Targeting Regional Economic Development*. New York: Routledge: 241-253.
- Maciejovsky, B., & Budescu, D. V. (2013). Markets as a structural solution to knowledge-sharing dilemmas. *Organizational Behavior and Human Decision Processes*, 120(2), 154. doi:10.1016/j.obhdp.2012.04.005
- Schuyler, R. (2015, Sept. 23). Realizing the Dream: Family Self-Sufficiency in Albemarle County & Charlottesville, Virginia. *Charlottesville Works Initiative*. <<http://cvillechamber.com/wp-content/uploads/2015/09/2015-Orange-Dot-Report-2.0-Online-Edition.pdf>>
- Sönmez, T. (2014). Cadet-branch matching. *ACM SIGecom Exchanges*, 13(1), 50-57. doi:10.1145/2692375.2692379
- Taylor, W. C. (2006, Mar. 6). Here's an idea: Let everyone have ideas. *New York Times*. <http://www.nytimes.com/2006/03/26/business/yourmoney/26mgmt.html?ex&_r=0>

Chapter 7: Summary and Conclusion

The orientation of urban development planning towards networks and associated tools, methodology, and theory are epistemic adaptations to the increasingly dynamic and technology-driven character of contemporary economic activity. Complexity, globalization, and innovation-driven feedbacks can leave development agents, whether workers, entrepreneurs, or planning researchers scrambling for a working model to guide behavior. Complexity and search dynamic challenges are inseparable functional issues for all the world's economic agents stuck with rationality bounded by networks (Simon 1991, p. 132). What you do not know, and what you do not see can certainly still hurt you given hard to predict global financial, commercial, and technological changes in markets. These systemic perception and prediction problems call for systemic solutions for economic adaptation.

With so much scale, uncertainty, and investment risk in contemporary economic systems, transnational corporations have created global networks of employees and exchanges that facilitate flows of resources and information. Much development research and theory concerns these global networks within and between urban regions, and the assessment of operational and attraction dynamics for global firms (Taylor and Derudder 2016). The scope of the development network studies presented here has largely focused on internal regional network dynamics, not urban external networks. The review chapter (2) introduced the global science of cities, evolutionary economics, and regional simulation science approaches to studying development dynamics, but these general network studies leave little for localities to actually plan. This research is excellent for comparison purposes but less helpful for guiding development decision-making.

In the introductory chapter, the research objectives including gathering data about the system to understand its genesis and structure, and to organize this data into categories such as network forms, functions, and feedbacks in an urban region. From there the research tasks included conceptualizing ways to simulate these dynamics using computer models towards better understanding their coevolving relationships, and other experiments to test development theory. With improvements in data, theory, and methodology, the final research goal was to conceptualize how to coordinate development information inputs and network processes to better synchronize

development activity towards improved adaptation of the regional system and its constituent network elements.

There are many research advantages to focusing on extremely local development network processes. Complex adaptive systems have emergent properties, so understanding bottom-up feedback dynamics is a necessary prerequisite for basic system functions. This is a fundamental point which Epstein (2006) presents with his generative social science approach to modeling epistemology: do you know/understand the real-world patterns well enough to grow the basic patterns in a computer model?

The grounded study chapters (3 &4) of the City of Roanoke attempted to discern commercial development patterns in neighboring communities as integrated spatial networks that organize socio-economic activities. The research questions sought answers as to what spatial components characterize regional and local development network activity. Subsequently, specific sites were studied to explore the investment and commercial information signals, and how agents interpreted them in their own work.

<p>a) <i>Which spatial characteristics characterize Roanoke development network activity?</i></p> <p>b) <i>What development information dynamics occur at specific Roanoke sites?</i></p>
<p>Network structural forms: Networks of centers, networks of land use, cooperative behavior norms at site, networks of perception and discovery, and activity coordination networks.</p> <p>Network development functions: Spatial network scaling, social network engaging, development network perceiving.</p> <p>Development forms and functions coevolve to shift network patterns relative to appreciating and depreciating feedbacks, and experimental targeting of investment opportunities.</p>

Development forms and functions coevolve to shift network patterns relative to appreciating and depreciating feedbacks, and experimental targeting of investment opportunities.

- These urban centers reflected urban webs of appreciating and depreciating feedbacks strongly impacting individual well-being and opportunities.
- Local development is a contact sport, and many populations do not have easy personal contact with valuable capital where they physically grow up, live, and shop.

- Physical capital is expensive to maintain, and subject to neglect and decline if not actively supported.
- Social capital can be strongly influenced by spatial patterns of physical capital, transportation dynamics, and cooperation norms to say nothing of the availability of emotional health, support, and bonding dynamics.
- The capital forms associated with personal and collective expertise and technologies are similarly subject to coevolving feedbacks driven by social, spatial, and financial network interactions at local to global scales.

All of these moving parts and flows are difficult enough to track, but economic survival is now increasingly driven by competitive advantages in technology, expertise, and innovation which are typically created, harnessed, and renewed by only a select number of global regions on industrial scales. Other regions must learn to adjust their assets towards ongoing adaptive innovation as well.

<i>c. How can complex urban development patterns be simulated?</i>
Add/subtract buildings and agents to understand movement and rent cost appreciation and depreciation.
Experiment with different coevolving sites, agents, groups, and business patterning. Potentially regionally scalable.

A third research question asked how complex urban development patterns might be simulated. However, while many urban dynamics can be modeled and integrated, innovation-driven city economies continue to defy a fully adaptive agent-based model (ABM) of generative development patterns.

- Innovation’s inherent unpredictable novelty makes it difficult to simulate.
- There are also different networks with different feedbacks functioning to support different goals by different agents operating at different scales.

A business leader or shopper may shift resources away from a community by moving production somewhere or shopping at a franchise that shifts profits out of town. Models can help us understand the distributional consequences of these feedbacks.

- These investment choices have systemic consequences when repeated and distributed.

An urban village's competitive role may facilitate or cannibalize the development processes of other communities in its city. Neighboring cities may compete for tax base supports and economic amenities setting regional networks against one another rather than towards mutual reinforcement.

- Bottom-up processes may be fundamental to development patterns, but the level of analysis has critical consequences for behavior, assessment, and standards of performance.

All these variables and relationships are difficult to capture in network planning models like computational simulations. Nonetheless, scholars such as Allen (2012) have claimed such models are more than possible, but they must be constantly monitored relative to real-world behaviors. When system behaviors shift outside predicted patterns, the model theory must be newly grounded and reinvented.

<p><i>d. How can urban development planning be defined computationally, and how might urban development planning systems be computationally enhanced toward adaptive functions at multiple spatial levels?</i></p>
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<p>By defining CUDP as integrated network and capital synchronization, a process to assess systemic change in sales and markets can be matched to macro-regional and micro-local investment plans to manage appreciation and depreciation patterns.</p>

<p>Network-oriented development for organizing signaling can support individual and collective perception and access to network resources and information critical for experimental targeting of emerging business models, customers, and sales.</p>
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The fourth and final research question asked how urban development networks might be *planned* or synchronized computationally to improve multi-scale adaptation to new economic conditions. ABMs and simulation science may still prove extremely useful as development planning tools despite their limitations for generating simulated innovation economies. Their chief contributions are in two essential epistemic tasks. Firstly, as a prediction and validation tool, simulations can track existing, real-world development dynamics, the assumptions of which underlie development policy decisions by governments and major employers.

- When real *patterns deviate from expected* variances, then something important is not known.

As Bohm (1998, p. 13) describes this process as occurring when categorical structures, or “an already known set of fundamental differences and similarities [i.e., models, paradigms, etc.]” are discovered to be no longer relevant. The transition, while psychologically difficult, can free research “to be attentive, alert, aware, and sensitive so it can discover a new order and thus create new structures of ideas and concepts.” This difficulty transitioning between models points to the inherent challenge of adaptive planning timing:

- It is incredibly difficult to recognize creeping capital obsolescence due to systemic situational ignorance of shifts in global and local economies.
- Furthermore, there are times when staying the course is extremely dangerous for a regional economy; it could lose a generation of workers and businesses.

Recursive tracking and prediction systems can help identify conceptual gaps in market understanding to support adaptive planning responses and re-modeling.

Additionally, by simulating contemporary or potential scenarios, various complex feedback dynamics can reveal disastrous macro-level regional patterns from certain micro-level decisions made by individuals, groups, businesses, or neighborhoods. Neal (2015) has called this the “micro-macro conceptual gap,” and network tools to bridge this gap are essential to utilizing complex dynamics to plan development as opposed to constantly creating unintended consequences at scales above or below a specific level of analysis.

- Perceiving a complex system “holistically” is essential. Simulation and computational social science data tracking tools are the only readily available contemporary means to do so.

There are many questions which these studies did not answer, but perhaps they can contribute to clarifying research opportunities and emphasizing their importance moving forward. The limitations of data availability, modeling, and associated practical challenges such as privacy, accuracy, validation, monitoring, administration, funding, human agency, democracy, and the speeds and levels of change are enormous practical challenges to implementing such a networked planning system. Tremendous humility is still necessary in terms of tools, responsibility, and existing societal assumptions. Social equity, social engineering, social disintegration, ecological sustainability, creatively

destructive capitalism, cultural dissolution, political manipulation and other long-standing challenges and critiques of contemporary societies may even be worsened through the use of such tools in certain governing contexts. **The primary balancing feedback to these challenges is ubiquitous, open, and instant access to critical economic investment information at a societal level.** Who watches the watchers? It is the watched who must, otherwise, the information and resource asymmetries will necessarily inhibit adaptation and accuracy of decision-making as coordination falls prey to insider trading, rent-capture, opportunity hoarding, and other corrupting influences.

With these challenges in mind, a network-oriented urban development planning system has been described (in chapter 6) to support three essential complexity-adjusting regional development planning tasks—prioritizing urban center placemaking, synchronizing capital and networks, and network intelligence structuring. The Roanoke case study identified many important structural and feedback characteristics related to local development processes.

- Spatial, social, and commercial patterns coevolve, so for the proper structuring of local, regional, and local-to-regional networks, some means of prioritizing neighborhood-level investment planning is essential.

Such integrated restructuring can help to fight off adverse systemic feedback loops like segregation, gentrification, social disintegration, shared historic trauma and stigma, as well as skill or infrastructure obsolescence and depreciation.

- Furthermore, sustaining creative, adaptive, and innovative activities means certain levels and focal points of such enterprises need to be targeted, supported, distributed, and coordinated on an ongoing basis.

Models and network tools can guide these decisions, potentially as feedback algorithms embedded into development planning processes.

Changes in markets and technology can yield sudden losses in various capital values throughout a region. This creates a great need to transform different forms of capital whose market values may have evaporated very quickly (Veetil 2016).

- Synchronizing and coordinating these capital transformations—in buildings and streets, in skills and knowledge, in social and business connections, in financial investments—is an inherent element of regional economic adaptation.

- The more changes in demand are detected the more shifts in capital patterns can be triggered and reinvested towards adjusting supply, experimenting with new businesses, or developing new markets to replace fading markets at the regional level. To the extent that the levels of transformation could be linked to regional data tracking of global-to-local change, the system might be functionally synchronized.

How prioritization, coordination, and decision-making are structured by network-orientation is the task of network intelligence development systems. Adam Smith's (2000) "invisible hand" has remained unseen long enough.

- The functioning of an economic system has to generate the signals necessary for distributed, bounded agents to engage in individual and collective calculations that bring about systemic network coordination.
- This process of scenario calculation has been called *framing*, and network-oriented development can potentially focus, collect, and distribute useful development signals to guide perception and support multi-level planning.
- Open self-organizing systems can be adaptive at both micro and macro-levels if an adequate network signaling structure exists.

Hannapi (2008, p. 285-286) argues that mixed strategies applied by different agents encountering different micro-level environments yield different experiences which frame distinct economic mental models. Through communication, these frames can be compared and divergent views potentially adjusted. He writes, "Choice thus is not simply derived from innate properties; *choice rather is part of an innovative process that enables an entity to build an internal model to guide its actions.* Decoupling model building somewhat from immediate perception provides certain degrees of freedom for possible models and thus enables the necessary variety, which evolutionary processes need for their processing" (emphasis original).

- For these reasons, development tools for information processing and modeling emerge as inherently systematic learning adaptations for surviving commercial complexity.

As network feedback processes, the concepts of computation, urban, development, and planning are less distinct theoretical constructs, they are synonyms for the information and resource organizing processes of collective human living.

If localities and regions are to more effectively organize these collective living processes, tremendous improvements in development model strategy framing, implementation, testing, recruitment, coordination, and revision at each spatial scale should support adaptation. Innovation-driven economic development offers a potential path to globally competitive advantage and a counter to value pressures on skills, technology, expertise and other capital depreciation. Communities, capital forms, collective decisions, and associated network structures and flows are the basic elements of regional innovative capacities.

Research into commercial neighborhood dynamics and computational social science applications, suggests network-oriented development can overtly focus and coordinate these activities regionally. The term “architecture of participation” has been used to describe collective intelligence tools (Taylor 2006). This study would add the architectures of perception, socio-spatial connectivity, and scale as collective development tools as well.

In the Introduction, the importance of understanding the social construction of economic opportunities was raised (see also Feldman 2014). It was the purpose of this research to contribute to the better understanding of the network construction of opportunities and capabilities in community and regional contexts, and the means by which different tools and methodologies might enhance future research and applied development planning efforts.

The specific economic behaviors, groups, and settings where development is framed, formed, and funded will necessarily vary. On the basis of spatial, survey, and inter-disciplinary development research, a general network-oriented approach to planning contemporary development has been outlined. Future research to construct, test, validate, and adapt urban development planning theories and modeling systems requires ongoing effort before implementation collaborations are feasible.

To advance network-oriented development research into the future, several areas of priority are apparent. By developing a working agent-based model with very specific spatial parameters, it could be possible to better define proximity’s relationship to social network engagement factors in urban space. Using such a model, different feedback patterns can be generated to explore both social network clustering and spatial network

clustering interrelationships. These can then be compared to the literature to see which dynamics have been previously identified empirically.

That research could support regional synthetic populations studies of CUDP to test different capital synchronization approaches. Spatial, social, and signaling strategies are important tools to structure development activities, but which are most effective for innovation-driven economic activities and investments? How should development planning regionally target investments in entrepreneurial experimental activity while coordinating/matching workforce investments? What surprising feedbacks or counterintuitive results emerge from these experiments?

Finally, given the various kinds of urban planning theories relating to complex system management, what are the similarities and differences extent in different collective intelligence approaches? In particular, is there any evidence that *network intelligence* is better suited for collective processing of economic information when compared to other planning approaches?

The general framework developed throughout this study can contribute to focusing and organizing development research to better understand urban complexity, coevolving feedbacks, and network structures. These topics, though, remain in their infancy and new theories are subject to rigorous testing and validation. The timing for this work would seem to be maturing. Interdisciplinary research, new data and analysis tools, as well as changes in changes in society and global economies together are pushing towards new approaches and discoveries. It is possible that the conditions are appropriate to soon achieve greater progress with enduring problems and emerging challenges. As we get more experience with complexity, adaptive systems' network forms and functions shift to the foreground of study. How urban complex adaptive systems ought to be developed is a topic of tremendous importance for all of the world's urban economies, societies, and systems of governance. It was the purpose of this study to contribute to explorations towards that end.

References

- Allen, P.M. (2012). Cities: The Visible Expression of Co-Evolving Complexity. In Portugali, J., Meyer, H., Stolk, E., Tan, E (Editors). *Complexity theories of cities have come of age: An overview with implications to urban planning and design*. New York: Springer: 67-89.
- Bohm, D., & Nichol, L. (1998). *On creativity* (1st ed.). New York; London; Routledge. doi:10.4324/9780203194713
- Epstein, J.M. 2006. *Generative Social Science: Studies in Agent-Based Computational Modeling*. Princeton, NJ: Princeton University Press.
- Feldman, M. P. (2014). The character of innovative places: Entrepreneurial strategy, economic development, and prosperity. *Small Business Economics*, 43(1), 9-20.
- Hanappi, H. (2008). The concept of choice: Why and how innovative behaviour is not just stochastic. *Journal of Evolutionary Economics*, 18(2), 275-289. doi:10.1007/s00191-007-0086-0
- Neal, Z.P. (2015). "Making Big Communities Small: Using Network Science to Understand the Ecological and Behavioral Requirements for Community Social Capital." *American Journal of Community Psychology* 55.3: 369-80.
- Simon, H. A. (1991). Bounded rationality and organizational learning. *Organization Science*, 2(1), 125-134. doi:10.1287/orsc.2.1.125
- Smith, A., & Cannan, E. (2000). *The wealth of nations*. New York: Modern Library.
- Taylor, W. C. (2006, Mar. 6). Here's an idea: Let everyone have ideas. *New York Times*. <http://www.nytimes.com/2006/03/26/business/yourmoney/26mgmt.html?ex&r=0>
- Taylor, P. J., & Derudder, B. (2016). *World city network: A global urban analysis* (Second ed.). Abingdon, Oxon: Routledge.
- Veetil, V. P. (2016). The mythology of capital in the twenty-first century. *Journal of Private Enterprise*, 31(1), 21.