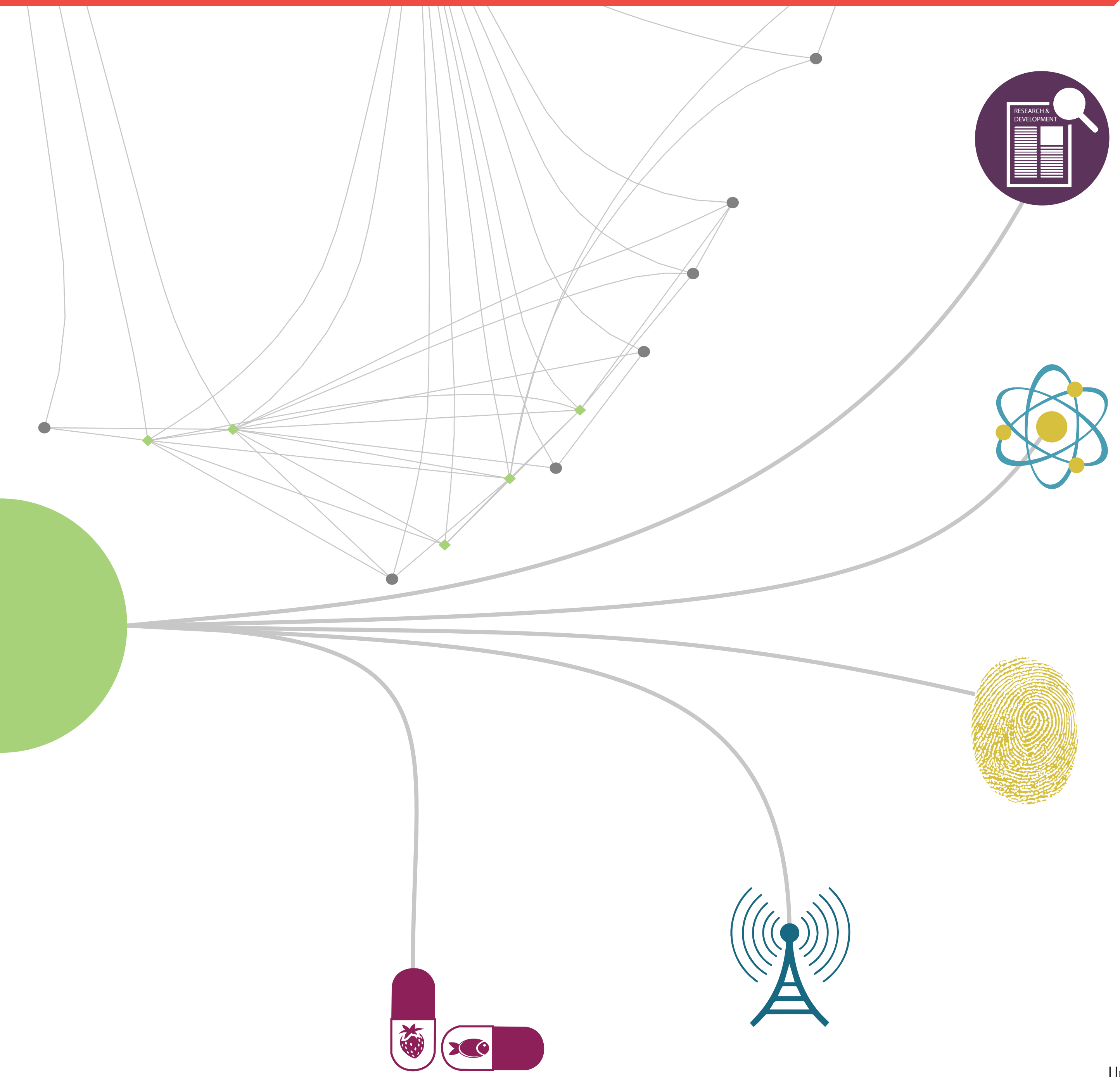
Innovation-Led Economic Development



Fall 2015
URSP 708 Studio
University of Maryland
School of Architecture, Planning and Preservation

Howard County, Maryland

Innovation-Led Economic Development in Howard County Maryland Using Cluster Analysis, Network Analysis and Spatial Analysis to Identify Economic Development Strategies

Prepared by
Students and Faculty
in the
Community Planning Studio
Urban Studies and Planning Program
School of Architecture, Planning and Preservation
University of Maryland, College Park
December 2015

with support from

Howard County Economic Development Authority

University of Maryland's Partnership for Action Learning in Sustainability (PALS)

The U.S. Economic Development Administration

Students

Tanya Allen
Emily Benoit
Razia Choudhry
Hanan Farhan
Kristen Franklin
Cole Greene
Andrea Haller
Jacob Johnson
Amina Mohamed
Karitsa Norman
Emma Prindle
Zachary Rockwell
David Schlie

Faculty
C. Scott Dempwolf, PhD
Assistant Research Professor
dempy@umd.edu (301) 405-6307

Table of Contents

Executive Summary

Identifying and fostering the growth of innovative companies has long been a focus of economic development. However, traditional methods of economic analysis often fail to identify sources of innovative growth because they are not designed to do so. Innovation is by definition ever-evolving and defies methods that focus on slow growth and historic trends. By investigating the nature of innovation, it is clear that methods to foster growth must themselves be innovative and able to capture change and complex relationships.

The focus of the Community Planning Studio was to identify innovation-led economic development strategies that would help spur innovation in Howard County, Maryland. In doing so, the class focused on a variety of economic data analysis methods to identify innovation activity in the county. The methods included traditional economic analysis which incorporated demographic, employment, education and commuting data. U.S Cluster Mapping was also used to identify industry clusters in the county- a method used by most economic development agencies. Spatial analysis was also used to create heat maps that identify clusters of innovative companies.

Assessing the demographic and economic characteristics of an area is an essential first step in developing community-based strategies. It provides orientation and initial direction on which to base further analysis. Cluster analysis is a popular tool that identifies a given area's major industry clusters and comparative advantages. We used these methods as a knowledge base for our in-depth spatial and network analyses. While we gained a sense of the County's advantages and major industries, we ultimately found that cluster analysis was limited in its ability to help us define innovation-led economic development strategies. Stats America and U.S. Cluster Mapping are tools that contain a wealth of information, but their calculation methods vary, and they rely on static industry definitions, broad categorization techniques, and past data to define clusters. This limits their ability to contribute to local strategies and identify innovative activities in a small and rapidly changing environment.

Spatial analysis methods were used to identify the locations of innovative companies in the context of their surroundings, taking into account land-use and zoning characteristics. Areas with concentrations of innovative companies were also analyzed. Using GIS software, kernel density and heat maps were created that identified areas where the companies were clustered. Regions with a relatively large number of companies in a small area became the focus once these maps had been created. Three clusters were identified but, due to surrounding conditions, infrastructure assets, and the prevalence of concentrations of companies within a specific industry, one cluster was selected as the focus of the rest of the analysis. The land use and zoning, combined with the presence of existing companies within this area is an important asset for enticing other innovative companies to locate in Howard County. However, several strategies could be implemented to truly position this area as an innovation district.

Our main method in this course was to analyze innovation activity in the County by using Network Analysis. We measured innovation activity by using data related to the different steps in the innovation process. These networks are comprised primarily of the people and organizations involved in innovation and the connections they share through those innovation activities. Science, Technology and Innovation (STI or herein simply 'innovation') is a process comprised of several different types of activities including research, invention, proof-of-concept, commercialization, and diffusion. These activities are carried out by people in various roles – researchers, inventors

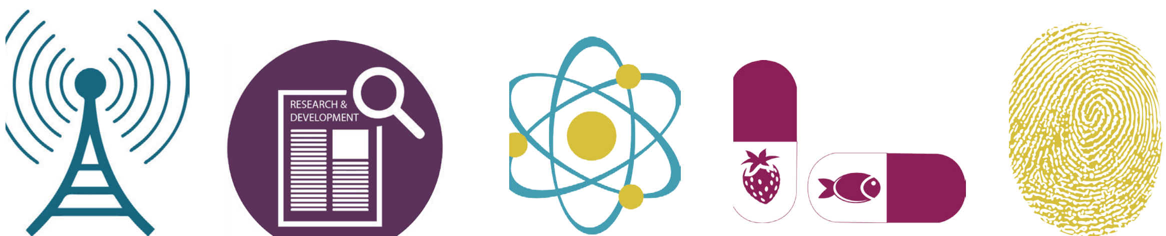
Figure 1: Map of Columbia Gateway Technology Park in Howard County, MD

and entrepreneurs for example; and the organizations (companies, institutions, agencies, etc.) that they are connected to. Other people and organizations in the network may be involved in supporting roles – providing funding, resources, ideas, know-how or social capital that helps the innovation process advance. In the network models people are represented as 'nodes' or 'vertices', and are connected to each other by lines (called 'ties' or 'edges') representing the relationships connecting them.

The various activities produce both tangible and intangible outputs including publications, intellectual property (IP), startups, prototypes and products. These products of innovation activities are also connected to the people and organizations involved through author, inventor, founder and ownership ties. After analyzing these networks, we found five main technology clusters located in Howard County:

Regenerative Medicine is for the most part a largely untapped industry in Howard County that has a lot of potential to grow. Figure 2 on the next page illustrates the Regenerative Medicine Innovation Cluster with targeted economic development strategies for the county.

From the network analysis, over 60 companies were identified as technology clusters. Each of the 60 companies are either situated within the County or have been identified as a company with ties to the County. Individual profiles were then created for each company with information regarding a company's size, location, funding, revenue, and activities. From there each company was classified as one of the five technology clusters obtained through our network analysis. Currently, the most active cluster within Howard County is Regenerative Medicine. These company profiles can be used by Howard County to start building relationships that will target innovation activity.



Telecommunications | Research & Development | Regenerative Medicine | Nutraceuticals | Defense/Intelligence/Security

So how do we spur innovation-led economic development in Howard County? We found that the multiple data analysis methods we applied illuminated a few key strategies for the County.

1. The county establish an innovation district to geographically target entrepreneurial activity related to regenerative medicine technology specifically near the Gateway Center at Snowden River Parkway

2. Develop Keystone companies with local industry leaders to spur an innovation ecosystem

3. Create a new approach to business attraction by targeting the small and mid sized growth-oriented technology-driven firms that have connections to Howard County but

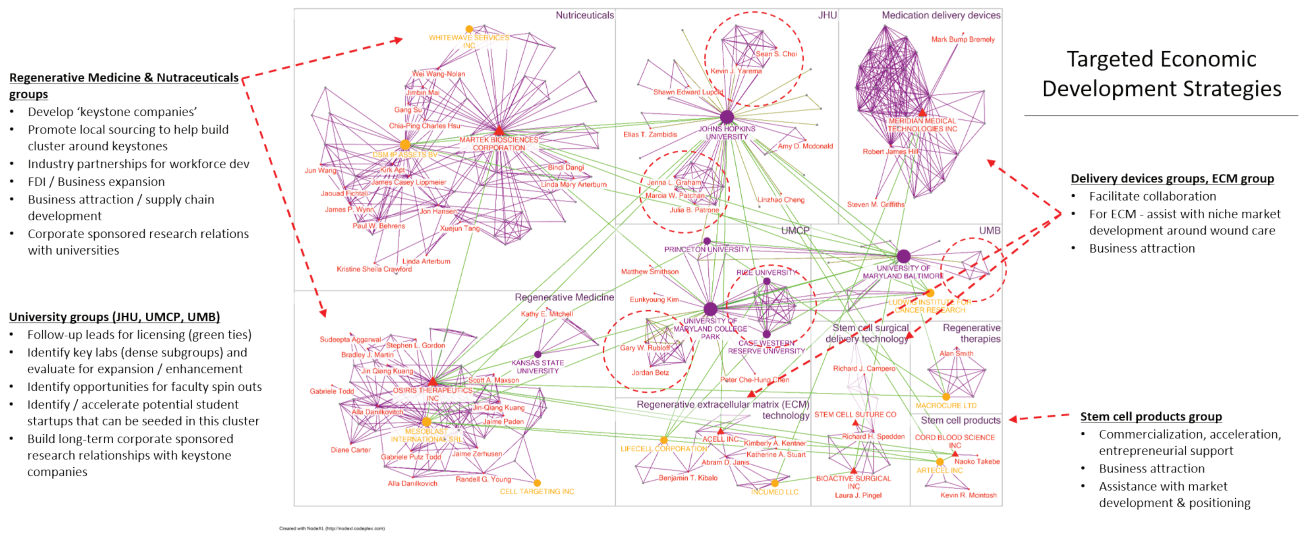


Figure 2: The Regenerative Medicine cluster in Howard County MD

have not yet located to the county

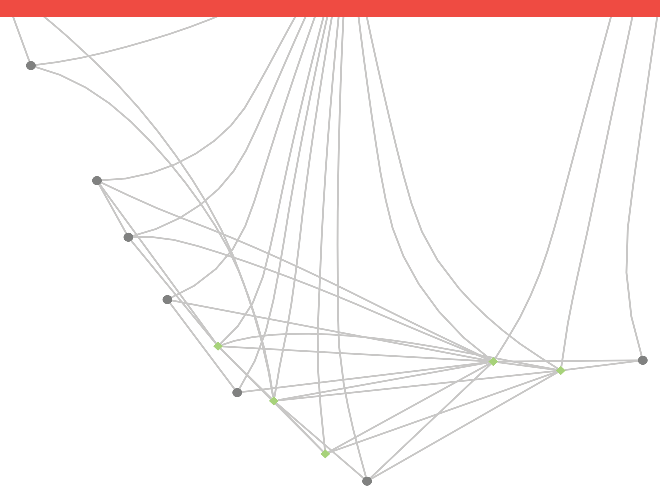
4. Utilize the 60 company profiles our research team has developed to start building a relationship

5. Facilitate growth within the Regenerative Medicine cluster by facilitating sponsorship of cluster-oriented research, targeting student startups and faculty spin-offs through accelerators and incubators

Chapter 1

Introduction

Innovation-Led Economic Development in Howard County Maryland Using Cluster Analysis, Network Analysis and Spatial Analysis to Identify Economic Development Strategies



Science, technology and innovation (STI) has long been viewed as an economic driver within our economy because STI produces new ideas, products and processes that lead to economic growth and job creation. We define an economic driver as any activity that accelerates this process of economic growth. In turn, economic growth affects the nature and speed of innovation. One example of an economic driver is basic research where most scientific discoveries may not directly contribute to new products and services but years down the line could significantly alter the current systems and ways of life (Stephan, 2015 p. 205). Economic growth is essential to match population growth and maintain competitiveness within a given system (Spruijt, Spanjaard, and Demouge, 2013). Although they may result in economic growth, "many innovative activities reside in functions not typically regarded as drivers of innovation and growth" (Stephan, 2015 p. 220). This understanding has prompted our study to include a wider variety of data points and evidence of interaction and innovation.

Innovation has historically been understood in a linear model where research is conducted, leading to development, production, and eventually, commercialization. However, this model oversimplifies a complex and messy process (Landau and Rosenberg, 1986). While economic gain is the end game in most cases, each step in the process promotes economic growth and responds to economic conditions. STI systems are "continuously and rapidly evolving" as they respond to these conditions . These complex interactions and processes need to be understood as they may influence expected outcomes (Freeman, 2009 p. 4). Current STI systems rely on the symbiotic relationship between private, public, and academic institutions that contribute to the overall body of knowledge and the application of that knowledge. The importance of interdisciplinary work should also be stressed here. There are two types of knowledge that contribute to the production of innovation: propositional knowledge, defined as scientific knowledge, and prescriptive knowledge, defined as technical capability (Stephan, 2014 p. 204). According to Joel Mokyr, an economic historian, the relationship of propositional knowledge and prescriptive knowledge enables innovation advancements to cross between knowledge disciplines and between the public and private sector boundaries (Stephan, 2014 p. 204). While the private sector relies on transmission of knowledge and recent scientific development, public institutions rely on the advancement of tools, equipment, and processes of the private industry to assist in the application of new research (Stephan, 2014 p. 209). While innovation is not strictly a linear process, it is the result of a more systemized approach to research and development that considers scientific and technological advances in research and application.

The Influence of Science and Technological Innovation on Economic Growth Technological and scientific advancement works within the economic framework to produce new services and products that in turn lead to economic growth. However, measuring the economic impact of a singular product or transformation of existing products is a difficult task. Innovation has a different character depending on the industry in which it occurs. Therefore, identical investment into different kinds of industries will require differing levels and types of research and development (R&D) and have different rates of return. Additionally, innovation is not an isolated phenomenon. For example, the economic effects of a particular technological innovation cannot be pinned down to a quarterly economic report because the innovation can spill over into other industries years down the line and find new use. There is no standard timeframe or concise way to measure the effects because an innovation can yield benefits for industries vastly different from that of its origination or may not be profitable until it is combined with the materials of another industry. Scientific research is also seen as a public good because of its potential application and not simply its current utility (Landau and Rosenberg 1986).

The system of innovation within academia "has evolved in science to create a reward system that encourages the production and sharing of knowledge" (Stephan, 2014 p. 7). Furthermore, the reciprocal relationship, or non-linear model, where people "use science to advance technology" and "use technology to advance science" helped cement a systematic or cyclical form of innovation. These interrelated ideas continue to drive the changing nature of innovation. According to Salter and Alexy, innovation is a main driver of economic growth and generally creates spillovers (2014 p. 28). The nature of innovation combines previous processes to form new systems that involve "new combinations of existing elements, bodies of knowledge or technology" (Salter and Alexy, 2014 p. 30). The Role of Innovation Clusters and Contributions to Economic Growth As individuals and businesses work to advance scientific knowledge and technological innovation, specialization has been a necessary outcome. Specialization, while it has been known to benefit the economy, can lead to a separation between disciplines (Landau and Rosenberg, 1986). Innovation clusters can effectively break down the barriers between industries and disciplines and allow for spillover of knowledge and resources, the benefits of which include the increase of current knowledge and the decrease in the cost associated with attaining it (Stephan, 2014 p. 206). This is both an answer to the economic constraints and the nature of innovation.

The challenge of pursuing economic growth through innovation varies amongst high income developed, emerging developing, and developing countries. In the high income developed countries, innovation tackles the process of sustainability "that give increasing premiums to insiders, to security and risk aversion, and to the maintenance of income and wealth" (Freeman, 2009 p. 14). The Role of Institutions and Contributions to Economic Growth Institutions play a vital role in creating an environment in which research becomes feasible, sharing new knowledge and advancements with private industry. The success of funding for research and development is both accessed and measured through academic publications. Academic articles serve an added purpose of informing private industry of the most recent research conducted, the primary form of knowledge exchange (Stephan, 2014 p. 215). Another manner in which innovation is measured is the number of patents awarded (ibid). While the awarding of patents, along with hiring of recent graduates, and joint ventures can assist in the sharing of research knowledge, it is not as heavily relied upon as other methods. The second most common way in which knowledge is shared is through formal and informal communication between researchers and the private sector. Subsequently, private industry relies on the content ascertained and the connections made through conferences and consultants (Stephan, 2014 p. 215). The spread of research and advances in science are made accessible through this shared relationship between academic institutions and industry.

The feasibility of research and innovation relies on investments and contributions from the public sector. The financial and political support that the government provides to academic institutions allows for research that focuses on technological and scientific advancement while pursuing what Stephan describes as "humanity's quest for basic understanding" (Stephan, 2014 p. 8). While private industry is focused on economic gains to commercially remain as a viable business model, public sector assistance allows for cost effective advancement of humanity. How Economics Influences Science, Technology, and Innovation Despite the promise of economic gain, innovation lies at the mercy of the market forces of the time.

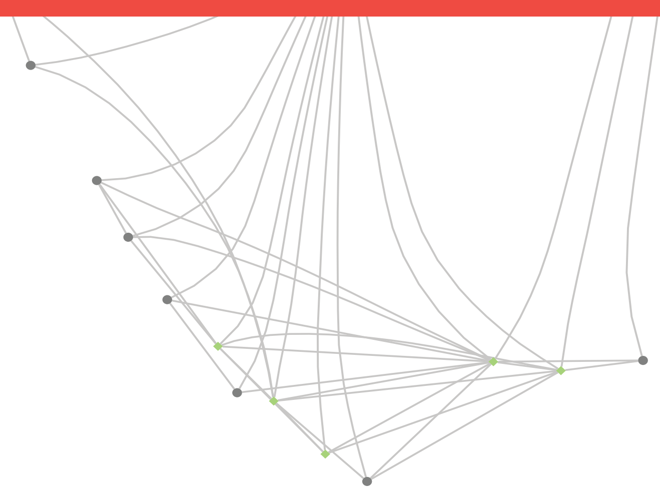
Innovation must be directed towards satisfying consumer demand. Stephan bluntly states, "Costs affect the pace of discovery," indicating that without the right economic conditions and financial backing, science, technology and innovation would not be possible (2014 p. 3). While R&D is undoubtedly associated with innovation, it is constantly affected by the economic climate. The incentive to spend money investing in scientific research and technological advancement depends on the comparative economic advantage of using old technologies. For example, the feasibility of producing a revolutionary new product may be reached long before the economic environment exists in which it becomes a priority and enters the marketplace (Landau and Rosenberg, 1986). Likewise, in a strained economic climate, technological and scientific innovation often takes a different form. When capital for investment is limited, the funds set aside for R&D predictably decrease and the riskiness of certain ventures also becomes a factor, turning the majority of funding to endeavors that have a more guaranteed return. As a result, the technological and scientific innovations that emerge are less likely to substantially change an industry and have far-reaching impacts (Archibugi and Filippetti, 2013 p. 135).

Innovation requires economic incentives, relying on venture capitalists to fund private firms and grants to fund academia. The National Institutes of Health and the National Science Foundation are significant contributors to academic research that enable universities to continue to fund research programs that push the boundaries of scientific discovery. These funds help universities cover the costs associated with research, which includes the physical building facilities, the incentive packages to draw faculty researchincentive packages to draw faculty researchers to these facilities, salary and stipends of researchers and graduate students, as well as the costs associated to the purchase of the research material and to care for the research (e.g. mice) (Stephan, 2014).

The cost associated with research and development can be prohibitive, which is why a relationship between public institutions and private firms is vital for research and development to be conducted as a manageable economic endeavor. The framework of the private sector is organized in a manner that allows for the research of universities to be transformed into products available to the mass market as well as to create spin-off ventures further contributing to economic growth (McKelvey, 2014 p. 77). The philosophy that innovation and R&D function as public goods is seen in the activities taken by the public sector in providing the financing necessary for these activities. Both the Small Business Innovation Research Program and the Small Business Technology Transfer help fill this role, providing the funding to help businesses push innovations past research into testing and commercial production.

Chapter 2

The Nature of Innovation



Defining Innovation

Innovation can have many different meanings, from the simplistic dictionary version, the introduction of something new, to the description of complex economic relationships. When discussing innovation as an economic development tool, it is important to identify a clear working definition to avoid subjective, varied interpretation. Providing a concise definition serves as a starting point and gives the discussion context, balancing the definition something new with the complex processes and forms innovation can take. Innovation can also manifest differently according to location and technology focus, so it can be useful to go one step further and tailor the definition to suit the needs of a certain locale. Here, we will present definitions of innovation as offered by experts, and what it can mean in a local context.

The 2010 National Academies of Science report Rising Above the Gathering Storm, Revisited describes innovation as being first to acquire and apply knowledge towards the creation of a sought after product or service, and emphasizes the importance of entrepreneurship (43). The multiple definitions of innovation cited in the National Academy s 2014 report Capturing Change in Science, Technology and Innovation share this emphasis on economics and value creation, describing it as the process of extracting economic value from novel activities. These definitions agree that innovation is a process that brings ideas to life, and whether they take the form of products, services or processes, they represent improvements on the status quo and must be produced or implemented. Implementation and feasibility are important dimensions of innovation; while failed attempts can be a part of the innovation process, it is products or processes that are ultimately launched into the marketplace that are impactful or effect change.

While the overall emphasis is that the products of innovation should create economic value, social value is included in some definitions as well (Capturing Change, p. 42). As the definition of innovation has evolved, its numerous scientific, technological, organizational, and financial dimensions have been acknowledged. Because innovation itself is ever-changing in nature, it is not easily confined to a single, static definition; rather, it is more useful to present a working, context-appropriate definition. For the purposes of this paper, we define innovation as a process that transforms ideas into new products (broadly defined) in the marketplace with the intent of creating value. This definition can be expanded by identifying the activities involved and the characteristics of the innovation process, which can also help with implementation of innovation concepts at a local scale.

The Recipe for Innovation

While exact definitions of innovation differ, there is consensus as to both the basic ingredients required for innovation and the steps in the innovation process. In general, the ingredients include knowledge, people, capital, and an appropriate ecosystem that will allow innovation to flourish. Within this general consensus, there are differences regarding emphasis and interpretation. For example, Rising Above the Gathering Storm, Revisited lists the ingredients of innovation as 1) new knowledge; 2) capable people; and 3) an environment that promotes innovation and entrepreneurship (p.44). The 2011 NAS report Measuring Impact focuses on trust among people and institutions, administrative structures allowing for rapid learning and adaptation, and historical ties. The 2012 NAS report Rising to the Challenge offers an interpretation that is more quantitative, identifying the three pillars of innovation as research and development investment, university funding, early-stage finance, and talent (2012, pg. xv). The ingredients referenced by

Hwang and Horowitt (2012) include ideas and talent, capital and investment, expertise, and a suitable social, political, and regulatory environment including keystone individuals and/or institutions that act as social bridges between disparate individuals.

The actors involved in creating, fostering, and implementing innovation can be broken down into two types: intangible actors, which can not be physically seen, and tangible actors. Some examples of intangible actors include talent, ideas, expertise, social networks, and the invisible hand. Tangible actors include specific individuals, technologies, private and public institutions, and the different levels of government. Both types of actors are complementary and play a major role in innovation.

Rising to the Challenge breaks the process of innovation into two main steps: the research/ creation of new ideas and the development/ implementation of these ideas into competitive products and services. (2012) These two main steps can be further broken down into research, invention, proof of concept, commercialization, and finally the manufacture of a product for distribution (reference to diagram). In the case of process innovations, widespread adoption of the idea or technique can be considered the final stage.

While the innovation process appears linear on paper, it is often far more complex. Innovation requires both an inventor and knowledge, but these ingredients alone are not sufficient. The story of ProFusion, a cutting-edge web search engine invented by two University of Kansas professors, illustrates this principle. ProFusions inventors, Susan and John Gauch,were confident that their technology was as good or better than that of its competitors, and experts seemed to agree (Hwang and Horowitt, 2012). However, the Gauches struggled with the commercialization process and ultimately failed to fully exploit the potential of their invention. Limited business savvy and a lack of access to the kinds of knowledge, capital, and connections they needed to help them navigate the process were partly to blame (Hwang and Horowitt, 2012). Two decades later, their former competitor Google is a global juggernaut while ProFusion is largely forgotten.

Similarly, some clever inventions need further refinement before the leap from invention to innovation can be made. Learning from failure is one dimension of the process of careful and continuous social exploration described by Pentland (2015), and successful innovators can often cite a string of previous failures that contributed to their eventual success. They are willing to test and refine their idea via informal discussions within their social network or formal academic research and publication, and go back to the drawing board again and again if things do not seem to add up. Some inventions move quickly through this process, some are discarded immediately, and some pass through multiple iterations of this cycle before finally moving on to the next stage. The process of moving from invention to innovation may be the same, but timing can differ substantially. The shape of a products path during the next phase, from invention to proof-of-concept and commercialization, is a function of early-stage finance, the regulatory environment, and relationships with keystone individuals or institutions. Steve Jobs and Steve Wozniak could build a handful of Apple computers by borrowing money and space from friends and family, but eventually needed access to more resources to meet growing demand. Had they not met angel investor and industry veteran Mike Markkula, who invested $250,000 in the fledgling company at a crucial stage, todays computer landscape might look totally different (Livingston, 2007). Harvards ability to patent and license its OncoMouse technology gave DuPont researchers the resources they needed to develop new medical treatments. At the same time, the zealous protection of this technology may have prevented other independent researchers from being able to take their own ideas to the next level (Stephan, 2012). The Gauches had ideas, investors, and industry buzz, but their failure to befriend a business-savvy keystone caused ProFusion s story to end too soon (Hwang and Horowitt, 2012). Timing during this phase is critical, as delays in moving from idea to market may compromise the process of innovation (Rising Above the Gathering Storm, 2010).

How government institutions fit into the innovation process remains a source of considerable debate. While most recipes for innovation address a government role, opinions differ as to where and how the government should be involved. Hwang and Horowitt advocate for government funding for small innovation-oriented businesses, contending that markets are inefficient when it comes to promoting innovation and note that government-subsidized capital was a quiet force behind many recent innovations brought to market by U.S. entities (Hwang and Horowitt, 2012). This theory is supported by a study analyzing the sources of award-winning innovations between the period 1970-2006 that found nearly a quarter of the inventions had come from firms that received SBIR funding (Block and Keller, 2008). Others argue that government investment in research may create distorted incentive structures that discourage truly groundbreaking research, particularly in the physical and biomedical sciences (Stephan, 2015). While there is some disagreement over what role the government should play, there is consensus that government is also a factor in the process of innovation.

Progress from one phase to the next is uncertain, and the right mix of ingredients at the right time is critical to moving ahead. Individuals with talents and expertise alone will not create innovation. It takes capital investments from different levels of government as well as the private sector. Technology shapes the way in which people, organizations, and institutions connect and communicate so that businesses, resources, and the establishment of businesses are not geographically confined. Customers are also important actors, from the earliest stages of innovation until the product is well-represented in the market. The hypothetical customer is what inspires an innovator, while the actual customer buying the innovative products completes the circle by creating economic value. In short, the process of innovation is dynamic and unpredictable. This is an important characteristic of innovation, and one of many that will be discussed further in the next section.

Characteristics of Innovation

We have previously discussed the definition innovation and the process by which it occurs. We now turn to the characteristics of innovation. This section will focus on the interactions that occur throughout the innovation process and why certain behavioral norms are so important to creating an innovative community. While the dynamic and unpredictable nature of innovation don t allow for any one individual or organization to control the innovation process, cultivating an environment that exhibits certain characteristics can increase the likelihood of innovation occurring.

The conventional economic theory that has driven economic development strategies to date is focused on rational choice and clusters. Rational choice theory states that when people act rationally to maximize their economic self interest, there will be net positive results on the macro level. While certain individuals may make poor decisions about who to trust or how to commercialize an invention, others will make the right decisions which will result in overall economic gain. However, when viewed at a micro-level, person-to-person level transactions are often limited by barriers such as geography, social networks, language, culture and trust (Hwang and Horowitt, 2012). The cluster approach to economic development looks to address the geographic barriers to innovation but does not address the other barriers.

When a community or a workplace is more engaged with each other and there are more interactions between members, production and creativity both increase. These increases stem from the collective intelligence that is achieved when ideas are abundant and flow freely (Pentland, 2014). Idea flow is the guiding principle for innovation. Great innovations never happen in a vacuum, ideas need to be discussed, tested, and commercialized as discussed in the previous section. With increased idea flow as a key underlying characteristic of innovation, we can discuss what characteristics contribute to increasing idea flow.

First and foremost there must be a high degree of trust. Lets use a simplified example of an inventor and a marketing guru (in reality there are likely to be many more actors involved). The inventor has a great idea for a product and the marketing guru knows how the product will perform in the marketplace. The inventor must take a leap of faith and trust the marketing guru and the marketing guru must value the trust of the inventor and not take advantage of it. While it may be tempting for the marketer to take the idea and achieve a short term gain, the collective result of this type of behavior creates a culture of distrust and ultimately stymies idea flow and innovation. Creating a culture of trust is a matter of social norms built up through repeated interactions between individuals. Role models are important in creating trust within networks because human behavior is often heavily influenced by social norms. This is true because people often shape their own actions from actions of individuals they respect. This strategy is much less costly than discovering their own path completely from scratch. In innovative communities, keystone individuals (people that are respected in the community) exhibit trust and cooperation, which in turn promotes such behavior throughout the group.

The concept of diversity is fundamental to innovation. When communities or organizations become calcified and formulaic, they often lose their competitive edge. Thus, a constant influx of new and different ideas and people is vital for innovation. The impact of homogenous thinking can be illustrated by a real world situation that occurred on an online financial trading platform/social network (eToro). Traders can share their trades and are compensated when other users copy their trades. Research into the data revealed that there were a few traders who were very successful and their ideas were followed by other traders who also saw success. Eventually, a bubble formed when traders began following those who were following others, etc. The end result was less return on investment for investors who heard the same ideas over and over and more return on investment for those who mixed in new ideas with proven ones (Altshuler Pan, 2013). A flow of ideas means nothing if every idea is the same, or comes from the same school of thought. That is why people with diverse academic backgrounds and skillsets are crucial to innovation systems.

Innovation is not geographically bounded. This is the biggest departure from traditional cluster-based economic development. While geographic proximity can play an important role in allowing idea flow to occur (through face-to-face meetings), limiting the scope of innovation to a geographically bounded region closes off a worldwide network of potential actors in the process. Today, communications technologies make it possible for partnerships to be created across vast distances. A bio-medical technology company in Howard County may benefit by teaming with an investor from Boston who has connections to a pharmaceutical company in Germany. While this may seem to be an obvious characteristic of innovation, connections across jurisdictional boundaries are often neglected or even discouraged by the jurisdictions themselves for fear of companies relocating. While a legitimate concern, places with connections spanning geographic boundaries are often seen as attractive places to do business.

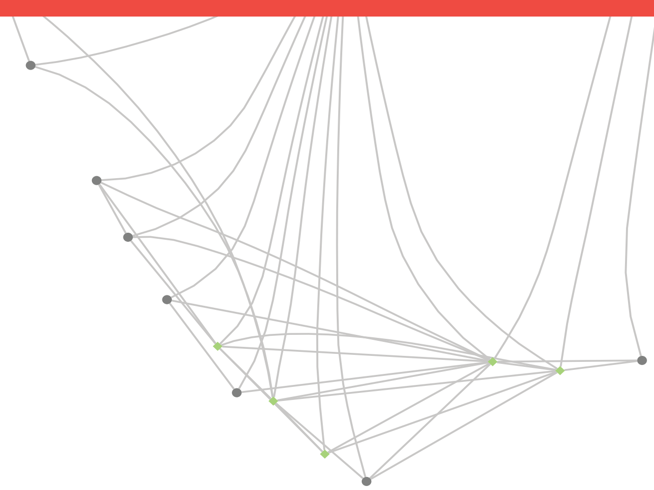
Innovation does not happen in a vacuum. It often takes several iterations of a similar idea to bring an innovative product to market and being connected to other fields of knowledge is often critical to coming out on top. To illustrate this point, we can turn to perhaps one of the most iconic innovations in human history; Thomas Edison s electric light bulb, which Steven Johnson recalls in his book, How We Got to Now: Six Innovations That Made the Modern World . Ironically, the light bulb is often associated with a moment of brilliance, but its invention was a longer, more complicated process. Edison filed a patent for his electric lamp in 1872, but the story actually begins in 1802 when British chemist, Humphry Davy used platinum filament and a battery to create a glow that lasted for several minutes. Between then and Edison s patent filing, 23 other patents were filed for light bulbs. Edison s biggest contribution was the carbonized bamboo filament that he and his team eventually decided to use (previous attempts had used substances such as platinum, iridium and other carbon-based materials). Once he had decided on bamboo, he sent a team to search the globe for the most incandescent bamboo in the world. One of Edison s representatives, William Moore, found such bamboo in China and Japan and struck a deal to import the bamboo for his lightbulbs. As Johnson explains:

> *The other key ingredient to Edison s success lay in the team he had assembled around him at Menlo Park, memorably known as the muckers. The muckers were strikingly diverse both in terms of professional expertise and nationality: the British mechanic Charles Batchelor, the Swiss machinist John Kruesi, the physicist and mathematician Francis Upton, and a dozen or so other draftsmen, chemists, and metalworkers. Because the Edison light bulb was not so much a single invention as a bricolage of small improvements, the diversity of the team turned out to be an essential advantage for Edison. Solving the problem of the filament, for instance, required a scientific understanding of electrical resistance and oxidation that Upton provided, complementing Edison s more untutored, intuitive style; and it was Batchelor s mechanical improvisations that enabled them to test so many different candidates for the filament itself. Menlo Park marked the beginning of an organizational form that would come to prominence in the twentieth century: the cross-disciplinary research and development lab. In this sense, the transformative ideas and technologies that came out of places such as Bell Labs and Xerox-PARC have their roots in Edison s workshop. Edison didn t just invent technology; he invented an entire system for inventing, a system that would come to dominate twentieth-century industry.*

As Edison s lightbulb story shows us, trust, diversity, geographic unboundedness, are essential characteristics of innovation. Edison trusted his cross-disciplinary and multicultural team and traversed continents in order to make bring the light bulb to market. When we think about innovation, we should remember that it is a process that involves many different actors, that it is random and chaotic, that it requires trust, that it is often the result of cross-pollination of ideas, and that it knows no bounds. When we look to innovation to build our economy, understanding its nature is the first step to building a community that supports and encourages it.

Chapter 3

Measuring Innovation and its Impacts



Innovation is a vital part of a locality s economic ecosystem and continued growth. It is important that the measurement of this phenomena be thorough and practical. There are numerous metrics that help assess innovation at different stages. These include innovation input metrics such as research and development spending, and grants as well as innovation output metrics like publication counts, patent counts, and Small Business Innovation Research (SBIR) awards. Other metrics measure parts of the innovation process including innovation indexes and clusters. This section will look in depth at the following metrics:

- Research & Development and Grants
- Publication and Patent Counts
- Prototyping
    - SBIR/STTR funding
- Commercialization
    - Start-ups
    - Innovation Clusters
    - Innovation Indexes
    - Innovation/Social Networks
- Solow Residual

Innovation Inputs

Research & Development Spending and Grants

The two metrics used to identify Innovation Inputs comprise of R&D spending and grant funding. Typically, the subsidy of funding for the two aforementioned metrics is allotted at the federal level. Once distributed, funds are then augmented at the State and sometimes County level. As a way of monitoring the allocated funds, surveys are administered by the National Center for Science and Engineering Statistics (NCSES) and the Business R&D and Innovation Survey (BRDIS). The NCSES serves as the national clearinghouse for the collection of innovation development data in science, engineering, technology and research (H.R., 2010). To obtain this data, surveys are administered cyclically to recipients of R&D spending and grant funding. Similarly, BRDIS dispenses periodical surveys that focus on the firms/individuals product and process of innovation. These results are the government s source for national estimates on U.S. innovation activity (Boroush, 2010). Much of the information obtained through NCSES and BRDIS surveys include firm/individual location (County and State) and business code. Other pertinent information that may be acquired includes; types of employees (scientists, engineers, etc.), the nature of the innovation (new product or new process), the area of focus (pharmaceutical, biotechnology, etc.), sales, patents, and trademarks (Litan, Wyckoff, & Fealing, 2014). The metrics obtained, are largely comparative by geography and technology.

Innovation Outputs

Patent and Publication Counts

Patents have proven to be another valuable source of information when assessing innovation. They offer detailed information about an idea at a specific benchmark in the innovation process. Patents offer specific information about the firms and organizations involved in the invention being patented. Each patent lists all the inventors involved and is also given an assignee, commonly a private firm or university that the inventors are working for. Individual patents are required to give location information of both the assignee of the patents and of each inventor included. Patent location data that can be aggregated at different geographic levels depending on the jurisdiction. They can be used for local or regional economic analysis. Patents also offer detailed information about the industries in which the patent is being applied for. Searchable patent information can be found from the United States Patent and Trade Office through the Trademark Electronic Search System. Information is also available through private sources. There are a number of challenges that arise from the format of patent information. Patents were designed to be accessed one entry at a time, not for counting purposes. Other issues arise with what information is listed on the patent.A company may choose to submit the patent with the location that the work was done or with the address of their corporate office. A university usually has one primary location but patents and publication may be worked on by a professor visiting from another university somewhere else. Academic publications follow a similar pattern. They offer specific information about the organizations and firms involved, the industry for which they are intended and the place of publication. Publication information was also not intended originally to be a measure of innovation and has limitations in this purpose. The information is not publically available like patents. It is available only through private sources like Elsevier or Web of Science.

Prototyping

A small portion of prototyping is measured in Phase I of both the Small Business Innovation Research (SBIR) program and the Small Business Technology Transfer (STTR) program operated by the Small Business Administration (SBA). The objective of Phase I, is to determine the feasibility of proposed innovation endeavors presented by various firms/individuals (Small Business Administration, 2014). A large emphasis is placed on each firms/individuals potential to commercialize. Distribution of funding for Phase I is awarded through eleven federal agencies. These funds are distributed competitively to companies based on the merits of their proposal. This information is then counted at the State, County, Regional, and Local levels in order to provide comparisons. By the SBA administering funding opportunities through the SBIR and the STTR, the SBA is able to construct a database that holds various data elements regarding each funded firm/individual. From these databases award amounts and annual reports for companies can be obtained by the public via the SBIR website. However applicant information, company registry, and commercialization may only be viewed by the SBA (Small Business Administration, 2014). Commercialization Once the companies have moved past the prototyping/proof of concept phase into commercialization their phase 1 SBIR and STTR funding may cease; causing firms/individuals to obtain funding through private and non-SBIR/STTR allocations (Small Business Administration, 2014). This sequence is known as Phase III of the SBIR and STTR program. if companies are still a part of the public funding of the SBIR and STTR programs at this point then they will continue to be in the database regarding SBIR and STTR recipients and data regarding firm awards, industry, and location will still be accessible.

Innovation Process Metrics

Start-Ups

Start-Ups are a common metric used to measure entrepreneurship within the Innovation Process. Start-Up location data is typically amassed at the regional and local level. To gain insight into business formation and growth, a majority of Start-Ups can be found in the Longitudinal Business Database (LBD) (Jarmin & Miranda, 2002). Sources such as the Business Register, the Economic Census and microdata surveys administered by the U.S. Census Bureau provide the numbers for the LBD (Jarmin & Miranda, 2002). Data included in the LBD consists of firm size, age, sector, business growth, and job gains to mention a few. Due to privacy concerns, this data is only available for use by researchers working on approved projects.

Innovation Clusters

Innovation clusters are a location based metric that looks at the concentration of related industries in a particular geography. This concentration of companies in theory shows that there are elements in place that attract these companies together whether it be shared resources or facilities such as universities nearby. This also shows that the area is uniquely competitive in that particular type of industry. This gives an indicator of what industries the proposed area should focus their work on promoting and assisting. These clusters can be identified at different levels of geography from counties up to regions and larger. Innovation clusters provide a peek into what industry or technology an area should focus on, but does not provide more granular information on what strategies to pursue in order to take advantage of this information (US Economic Development Administration, Harvard Business School, 2014).

Innovation Indexes

The innovation index is another method that is used to compare places based on how innovative they are. This method brings together several innovation measures to create a measure that reflects multiple innovation inputs including patent counts, research and development spending, change in hi-tech employment share, average unemployment rate, and population ages 25 to 64 with bachelor s degree (U.S. Economic Development Administration). Indexes are most useful as a means of comparing one geographic area to another when there are multiple interacting variables. Innovation indexes are employed at various levels of geography including global innovation indexes that compare countries, State comparison indexes such as the StatsAmerica Innovation index, and in rare cases at the municipal level such as in New York City (New York City Economic Development Corporation, 2011) (Cornell University, INSEAD, WIPO, 2015)(US Economic Development Administration, n.d.)

Innovation Social Networks

For our project we use the information listed in patents and research grants to develop a social network of who s working with whom. Rather than look at the total number of patents we are trying to locate potential clusters of people and organizations in common industries with some tie to Howard County. We look for strong ties, which are direct connections between individuals or organizations and weak ties, which are potential connections. They include firm, industry and geographic specific data and can be conducted at local or regional scope. The data is available through primarily public sources.

Innovation Outcomes

Solow Residual

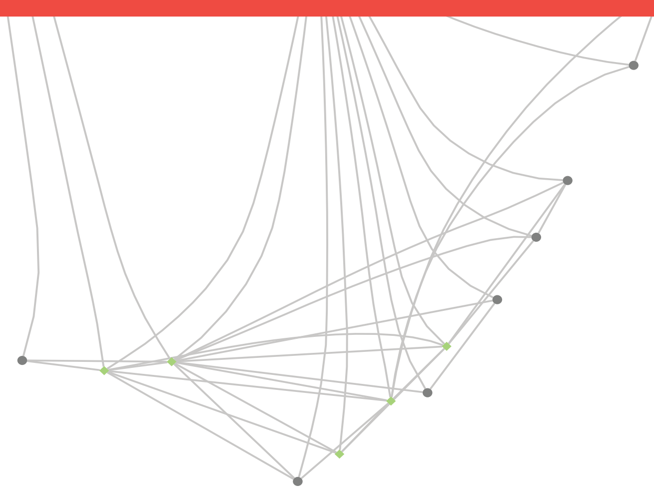
The measurement of innovation is mostly done through the inputs and outputs of the process. However, there is another way to try to see if there is innovation occurring in an area. This is through the Solow Residual which is a roundabout way of doing this. The basic idea of how this metric works is to measure economic growth by known means, capital accumulation and labor change, and what can t be explained by these is the Solow Residual (Investopedia, n.d.). So this metric is not measuring innovation per se, but the economic growth that is attributable to technological change. This technological change is generally considered to mean innovation. A main issue with this metric is what an economic developer can do with the information since it is a macroeconomic measure so it is not useful at the local level. Since the residual does not provide information on how to improve upon the innovation that drives the economic growth it provides no benefit to a jurisdiction. Also, the residual is restricted to use at the national level so comparisons can only be made between countries which limits the measures use.

Conclusion

The measurement of innovation is important if economic development practitioners and city officials want to be able to harness the power of this phenomena. This means it will be important for these methods to be both understandable and practical so that the results of these measurements can properly guide policy and practice.

Chapter 4

Innovation-Led Economic Development



Innovation Led Economic Development engages different resources from different levels of government including Federal, State, and Local sources. Funding for research and development, accelerators, makerspaces, and innovation districts – all discussed below - are some of the ways in which innovation is spurred in communities. These resources are targeted specifically for job creation within the technology sector of the economy.

What are the principal activities or tools involved in an ILED strategy?

How do we create an innovation ecosystem? Essentially, the components that determine the successful implementation of ILED can be divided into two major parts: The hardware (assets) and the software (culture). One can also describe it as the overlay of economic (firms and institutions as innovation drivers), physical (public or private, accessible spaces) as well as networking (ties between actors that facilitate flow of ideas) assets. Both parts work together to foster a nurturing business climate that helps innovation networks flourish while their companies grow and succeed. Some of the tools and strategies involved in ILED include:

- Innovation Districts
- Makerspaces, Accelerators & Coworking Spaces
- Local, State, and Federal Initiatives

Innovation Districts

Innovation Districts constitute one approach through which innovation ecosystems can be established. These can be defined as areas within specific geographic boundaries, where one can find a combination of anchor institutions, start-ups as well as established companies, business incubators and accelerators. Within this intertwined framework of different actors, the business climate consists of open collaboration, trust relationships as well as mutually beneficial idea sharing. The location of such innovation districts can range from downtowns and midtowns of central cities to industrial, suburban or even exurban areas. The method to build such geographically defined innovation ecosystems is to pre-establish a collaborative leadership network and link those actors to a specific growth vision that should be achieved. Moreover, a skilled workforce and a well-developed infrastructure constitutes the innovation drivers of the district (Katz & Wagner, 2014, p. 1-14). Especially important in this context is the community engagement component as it is particularly important factor in developing distressed neighborhoods and having the community involved during the development process early on is vital to the success of these strategies. Chattanooga, Tennessee's 140 Acre Innovation District Chattanooga has used its three main assets to create an innovation district: quality placemaking, unusual anchor institutions, and a highly collaborative innovation ecosystem.

1. Chattanooga has invested in its former industrial downtown and transformed it with riverfront parks and cultural institutions in order to create downtown living scene.
2. Chattanooga's economic revival came from investments from the Electric Power Board of Chattanooga and the Department of Energy's Smart Grid and have created "the world's most extensive municipal high-speed internet networks."
3. Chattanooga's innovation district was created only through genuine collaboration between public, private, and civic institutions

Source: http://www.brookings.edu/blogs/the-avenue/posts/2015/09/29-innovation-district-chattanooga-katz

Makerspaces, Accelerators, & Coworking Spaces

Operating on a more micro level compared to innovation districts, makerspace and co-working spaces are effective methods to foster the flow of ideas as well as prototype creation among diverse group of people and thus, spurring innovation. Makerspaces describe physical locations where tools and sometimes expertise are provided to a wide range of individuals within a collaborative community environment. Co-working space similarly offers a physical environment in which people can work, exchange ideas and create closer relationships with each other. Compared to makerspaces, co-working space focuses more on establishing ties and fostering the flow of ideas instead of producing specific prototypes as a business startup.

Oxygen Accelerator is a British company that focuses on supporting startups in the technology sector. In order to increase their chances of success, the company offers an intensive program to the participants, providing expertise, experience, angel investment as well as social networks connections.

Source:http://www.oxygenaccelerator.com/accelerator/

Local, State, & Federal Actions

In this context, local, state and federal action play a key role in providing major incentives to foster and accelerate ILED. For instance, according to the SSTI report on "Trends in Tech-based Economic Development: Local, State and Federal Action in 2013", promoting economic growth through targeted expansion of research capacity as well as commercializing research is an effective long term strategy (SSTI, 2013, p. 1-32). In addition, revising and implementing a higher education policy to fulfill the increased demand for a highly skilled workforce that requires fewer training resources, is another effort that can be made on a local as well as state level. Thus, investing in skilled workforce development programs is fundamental as an innovation driver. Another strategy consists of increasing access to capital by providing local and regional funding programs as well as offering tax incentives is a common policy effort to ensure economic development. In this regard, implementation and support of accelerators and tech hubs are core elements of ILED. Small business incubators and accelerators support startups with tools and strategies to succeed as a business. Taking this into consideration, the aspect of maintaining a social network that provides the foundation for active interaction and exchange of ideas is essential. Those kinds of ideas are often developed during research on a university level. Universities serve as an important connection between research and the private sector and often provide the social as well as physical network that can spur entrepreneurship. For ILED to function, public and private sectors have to collaborate and benefit from each other. In general, promoting a culture of entrepreneurship on both public and private level is fundamental in creating a business climate that encourages risk-taking, angel investment activity, community as well as media support and eventually changes conservative entrepreneurial corporate culture into an innovative one.

What problems or opportunities do ILED strategies address?

ILED strategies address stagnant economies by tapping into existing resources in order to create job and improve the local economy. Big economic gains are achievable through Innovation Led Economic Development strategies that can fuel job growth. Increased innovation and start-ups are the ultimate job creators that start with ingenious ideas that take risk and create economic value and gains for the American economy. For example, Brad Feld's discusses in his new book Startup Communities his experience in building an entrepreneurial ecosystem in Boulder, Colorado. To build this ecosystem Feld spent a lot of time creating connections and relationships among entrepreneurs, mentors, and education institutions (Feld, 2012). Over the long term, relationship building and social networks can improve stagnant economies.

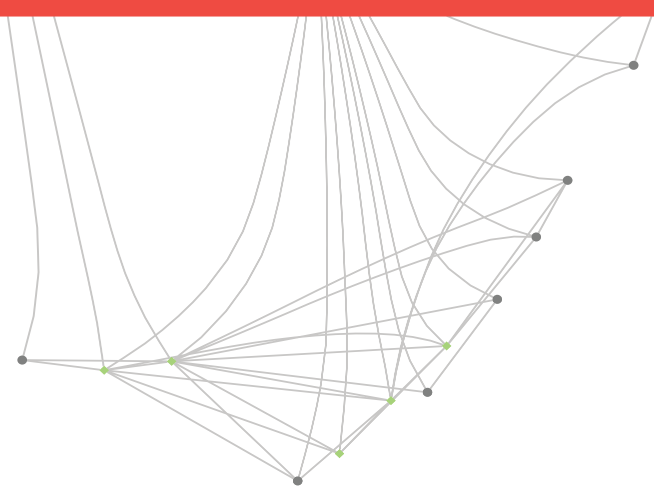
For ILED strategies to work efficiently, it is important that initiatives promote economic growth in targeted sectors that are either unique to the local economy or have the potential to grow. This can be done through expanding research capacity at local educational institutions and providing resources to help commercialize the research. In many states Governors and policymakers prioritized funding toward these types of initiatives in 2013 (SSTI, 2013) to prepare the economic environment for expanding economic value/gain and new job growth in high-tech fields. For instance, in the state of Colorado, lawmakers approved the launch of an advanced industries accelerator program to provide grants for proof-of-concept and infrastructure (SSTI, 2013). Many states have passed laws and made policies regarding expanding research capacity and commercializing the research, however, the states of New York's policy making role has particularly been pretty impressive in this regard.

In order to adopt ILED strategies for better economic gain, a community's workforce must possess the necessary skills. A recent survey of 24 countries found that U.S adults are less proficient in basic reading, math, and problem solving skills compared to many of their international counterparts (SSTI, 2013). As such, U.S. economic policies should be geared toward reversing this trend by directing resources towards workforce training programs. This skill mismatch problem has captured policymakers and practitioners' attention, and they are in quest of capitalizing on shifting demographics of U.S population. Recruiting more minorities, and females, and education and training more focused on STEM (Science, Technology, Engineering, Medicine) fields are popular approaches. For instance, in the state of Maryland, lawmaker passed a bill establishing the Maryland Employment Advancement Right Now (EARN) program and also provided $4.5 million in FY14 budget for competitive grants to bridge the gap between employer needs and worker skills through education and training. This is an example of an industry partnership that can better connect workforce training collaborations between business, government, and nonprofit organizations. Until 2013, including Maryland, 17 States has passed bills to address the skill mismatch between businesses and employees focusing on investing in skilled workforce.

R&D (Research & Development) sector is quite active in the U.S, and is effective in trying to innovate more and faster for common good and economic gain. However, for this purpose, significant public funding is being provided to R&D sector. Therefore the transparency issue aroused and increased scrutiny surrounding public investments prompted the passage of legislation in several states aimed at greater accountability for economic development activities. Many states have taken forefront position in this regard and have passed laws to bring more transparency and accountability to economic development departments in those states. For instance, Gov. Mike Pence of Indiana signed a bill that specifically requires the Indiana Economic Development Corp. to aggregate information on performance goals, jobs created, expected jobs, recaptured incentives and tax credits claimed each year.

Chapter 5

Traditional Economic Development Analysis



Introduction Located in central Maryland thirty minutes west of Baltimore and an hour north of the nation s capital, Howard County has a strategic position within a strong metropolitan economy. Johns Hopkins University s Applied Physics Lab, Lorien Health Systems, and Leidos (formerly SAIC) call Howard County home and are major employers in the County each employing over 1,000 workers. The area s high income and recognition as one of the top places to live in the country show that the County has a great deal of appeal and opportunity to offer current and potential residents and businesses. Demographics Howard County, according to the American Community Survey 2014 5-year estimates, has a total population of 299,269 people and a median age of 38.6. Howard County is among the most affluent counties in the U.S., with a median household income of $110,133 as of the 2014 ACS 5-year estimates. The County is fairly racially diverse; the population is 61 percent white, 18 percent black, 15 percent Asian and 6 percent Hispanic. According to ACS 2014 5-year estimates, close to 19 percent of Howard County s residents are born in a foreign country while 23 percent speak a language other than English at home.

Workforce and Education Howard County has high levels of educational attainment and a strong labor force. Of the population over 25 years of age, almost 95 percent have a high school diploma while 60 percent hold a bachelor s degree or higher. Of adults 16 and over, 170,382 are in the labor force, according to ACS 2010-2014 estimates. As of the U.S. Census 2013 County Business Pattern data, there are 8,946 establishments in Howard County.

Commuting Analysis of the commuting patterns of Howard County shows that the majority of the residents also work in the vicinity, but many work outside of the County and many commute in. 112,426 workers live outside but commute into the County, 99,724 live in but commute out of the County, and only 37,697 people both live and work in Howard County, according to U.S. Census and LEHD s 2013 on the map analysis. (http://onthemap.ces.census.gov/, image source) The average commuting time for residents is 30 minutes and 27% of the residents work in Howard County, 14% work in Montgomery County, 11% work in Baltimore City and about 10% each work in Baltimore County, Anne Arundel County, and Prince George s County.

Innovation Index

The innovation index is a product of StatsAmerica and is a tool that measures innovation potential by taking into account human capital, economic dynamics, productivity & employment and economic well-being. Comparing Howard County, Maryland, and the U.S., Howard County has a strong innovation index, indicating that by traditional measures, Howard County has a significant advantage for development of an innovation economy.

Figure: 2

Retrieved from: http://www.statsamerica.org/innovation/innovation_index/index_display.asp

Howard County Cluster Analysis

Results from two major sources cluster analysis resources, U.S. Cluster Mapping and StatsAmerica, have been used to analyze the industry clusters in Howard County according to the most recent available data.

U.S. Cluster Mapping

Table 1: Top six traded clusters listed by highest employment location quotient as identified by the U.S. Cluster Mapping website.

Description	Cluster - Employment	Cluster Employment LQ
Marketing, design and publishing	7,805	3.1
Environmental services	396	2.31
Communications equipment and services	2,000	2.16
Recreational and Small Electric Goods	528	1.71
Education and knowledge creation	10,018	1.69
Business Services	35,828	1.64

Table: 1 Top Industry Clusters by Employment Location Quotient (2013)
Data Source: www.clustermapping.us

Marketing, Design and Publishing

Among all the identified top clusters, the Marketing, Design, and Publishing cluster has the largest LQ value of 3.10 and 7,805 jobs. Industry clusters which have both high LQ and relatively high total employment typically form a region s economic base. Both LQ value and the number of jobs for the Marketing, Design, and Publishing cluster demonstrate this cluster s importance for the County s economy. Advertising Related Services sub-cluster is home to 3,969 of the total employees of Marketing, Design and Publishing cluster, followed by 3,530 employees in the Other Marketing Related Services sub-cluster. Maryland ranks 11th in the nation employing 8,719 people in Advertising Related Services sub-cluster, and out of those 8,719 jobs, almost half of them are alone in the Howard County; this shows that Advertising Related Services sub-cluster does have a strong economic base for the Howard County. Also, it is encouraging to note that analysis of previous few years shows that both Advertising Related Services and Other Marketing Related Services sub-clusters are among the fast growing industry clusters in Howard County and taking Maryland s ranking in these sub-clusters up every year.

Environmental Services

The Environmental Services cluster in Howard County has a very high LQ at 2.08 for a cluster that employ very few people; U.S. Cluster Mapping lists current Environmental Services or its current employment at 396. The cluster is broken into two smaller sectors: Waste Processing and Waste Collection. Howard County ranks 34th in Waste Processing and 120th in Waste Management among all U.S. counties. While the County remains at the forefront in these sectors, they are slowly declining with an estimated job loss of 59 between 1998 and 2013.

Communications Equipment and Services

The Communications Equipment and Services cluster has a slightly lower LQ than Environmental Services but employs more people than Environmental Services and Recreational and Small Electrical Goods at approximately 2,000 employees. The cluster consists primarily of the Communications Equipment and Communication Services subclusters. While the Communications Equipment subcluster has lost over 300 jobs in the last 15 years, the Communications Services subcluster has added over 800 and is likely to remain an important cluster/source of employment in Howard County for some time. One of the largest employers in Howard County is Verizon. With over 1,300 employees this firm likely contributes significantly to the strength of this cluster.

Recreational and Small Electric Goods

With a strong LQ of 1.71, the Recreational and Small Electric Goods cluster has a reasonable number of jobs at 528. The LQ value of this cluster shows that the County does have a good economic base in this sector. However, it is encouraging to note that the analysis of past employment data shows that the number of jobs is steadily increasing, and the County can potentially grow in this sector and increase its economic base. The Recreational and Decorative Goods sub-cluster is the main source of employment with 395 jobs in Recreational and Small Electric Goods cluster.

Education and Knowledge Creation

According to U.S. Cluster Mapping, as of 2013, Howard Countys Education and Knowledge Creation cluster employs 10,018 people and has a location quotient of 1.69. The Research Organization subcluster is home to 8,295 of these employees, distantly followed by 579 employees in the Training Programs subcluster, 550 in Colleges, Universities, and Professional Schools, 375 in Education Support Services, and 219 in Professional Organizations. CMlink The significant Howard County Research Organization subcluster ranks 16th in the U.S. in terms of employment, and the Baltimore-Washington-Northern Virginia Economic Area ranks 2nd in the U.S., outranked only by New York City. CMlink

Business Services

The Business Services cluster in Howard County employs 35,828 people, with a location quotient of 1.64. The top subcluster is Computer Services, employing 13,158, and ranks Howard County 32nd in the country in employment. Computer Services is followed by Corporate Headquarters at 7,655, Business Support Services, 6,029, and Engineering Services with 5,413. Consulting services has 2,502 employees, with Employment Placement Services, Architectural and Drafting Services, and Ground Passenger Transportation providing smaller shares of employment. CMlink The Baltimore-Washington-Northern Virginia Economic Area ranks first in the nation in Computer Services, employing a total of 248,924 people.

StatsAmerica

Table 2 shows the top clusters in Howard County according to StatsAmerica.

Description	QCEW Cluster - Employment	Cluster Employment LQ
Info. Tech. & Telecommunications	20,555	3.37
Defense & Security	22,936	2.62
Business & Financial Services	29,312	2.08
~~Energy (Fossil & Renewable)~~	~~14,295~~	~~1.99~~
Advanced Materials	9,326	1.81
Computer & Elect. Product Mfg	1,371	1.1

Table 2: The top traded clusters by highest employment location quotient as identified by the StatsAmerica website. Data Source: www.statsamerica.org

Information Technology & Telecommunication

With the largest LQ value of 3.37, the Information Technology & Telecommunications cluster provides 20,555 total jobs in Howard County. A high LQ value paired with high employment indicates that the Information Technology cluster is one of the major economic bases for Howard County. For this cluster, both the LQ value and the numbers of jobs are encouraging, showing that the Information Technology & Telecommunications cluster is a source of potential economic opportunities for Howard County.

Defense & Security

Defense & Security is the second strongest cluster is the in Howard County with an impressive LQ value of 2.62. The Defense & Security cluster has been growing in the past few years and no doubt Howard Countys strategic location near Federal government agencies plays a key role. In 2010, the LQ for the Defense & Security cluster was 2.27, a value which has since increased dramatically to 3.37. This indicates strong growth in this sector, and that the Defense and Security Cluster may be important to Howard Countys economic future.

Business and Financial Services

This is the largest cluster for employment in Howard County with almost 30,000 employees. It also has a relatively high LQ of 2.08. This combination of factors makes this cluster important for the County. One drawback is that the definition of this cluster includes a very wide variety of establishments, encompassing everything from architectural services to law offices to advertising agencies which makes it difficult to determine the areas of strength for the County within the cluster. It includes by far the most number of establishments of any clusters at over 2,390 (out of 9,259 total in the County).

Energy (Fossil and Renewable)

Energy appears as a major cluster in both employment numbers and LQ. Although this sector has grown in terms of employment between 2010 and 2013, from 13,756 employees to 14,296, the LQ has dropped somewhat from 2.12 to 1.99. While this sector remains strong for Howard County, the LQ could be a sign that the County is losing its competitive edge in this cluster.

Advanced Materials

Howard Countys Advanced Materials cluster employs 9,326 people, with a location quotient of 1.81 and 155 establishments.. Advanced Materials encompasses everything from fiber optic cable manufacturing to office machinery manufacturing to scientific research and development services. Computer and Electronic Product Manufacturing Howard Countys Computer and Electronic Product Manufacturing cluster employs 1,371 people and has a location quotient of 1.1. Howard County has 34 establishments in this cluster, and there are no subcategories.

Engineering Services (54171 NAICS code)

According to StatsAmerica the Energy Cluster is the 4th biggest cluster in the county in terms of employment location quotient and has an LQ of 1.99. Within this cluster, however, are a variety of industries which may or may not accurately reflect what would typically be considered energy-related industries. Among them are engineering services and testing laboratories which may also be incorporating some of the firms that are also included in the Defense and Security or Business and Financial

Services Clusters, creating a potential false impression of a strong industry.

Notably included in the Energy Cluster is the NAICS Code 54171, Engineering Services. It has a very high 9.6 LQ as well as 2,000 jobs. Firms included in this code are boosting the LQ result for the overall Energy Cluster . This more detailed information is extremely valuable, and it is worth for Howard County to plan a further growth strategy for 54171 NAICS Code industries, rather than the entirety of the Energy Sector .

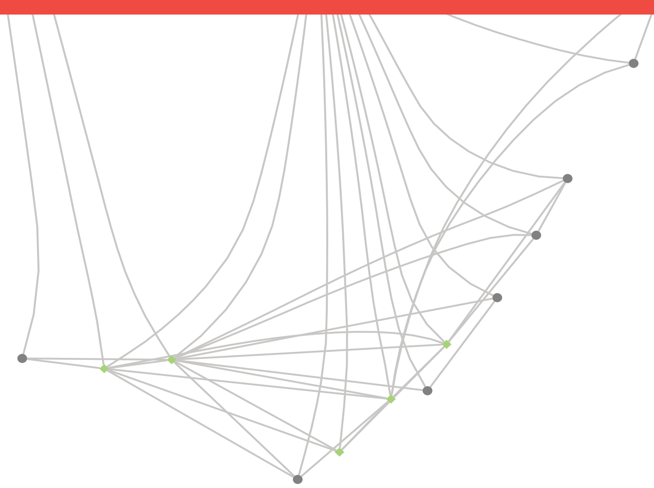
Wireless Telecommunications Carriers (51721 NAICS code)

Another example of large employment LQ values that are buried under agglomerated clusters is Wireless Telecommunications Carriers, NAICS Code 51721. According to U.S. Cluster Mapping, the Communications Equipment and Services cluster is the third largest cluster in Howard County with an LQ value of 2.16, and according to StatsAmerica the Information Technology & Telecommunication cluster is the largest in Howard County with a 3.37 employment LQ. If further analysis is done by looking into specific industry NAICS code for telecommunication-related industries, it shows that industry cluster with NAICS code 51721 which is Wireless Telecommunications Carriers has a 9.69 LQ. This significantly higher LQ indicates that the strength of this more specific industry is hidden by the relatively low LQ of the larger cluster.

U.S. Cluster Mapping and StatsAmerica are two well-respected, national websites often relied upon for cluster identification and analysis. However, they use different methods to define clusters, and therefore can yield different and sometimes conflicting results, as seen in the case of Howard County. While they both use NAICS industry codes for individual firms, they are aggregated differently into larger categories, as in the case of U.S. Cluster Mapping s subclusters. Some of these subclusters may be very significant compared to their subcluster mates, but their strength is diluted by counting the weak and strong in the same overall cluster. Furthermore, US Cluster Mapping assigns NAICS codes to only cluster, while StatsAmerica allows one code to be counted in multiple clusters. Where innovation is concerned, cluster definitions can be restrictive in that they are static and do not necessarily adjust to include new, emerging fields and technologies, which might be significant sources of growth potential.

Chapter 6

Spatial Analysis: Creating an Innovation District



When conducting a spatial analysis of the innovation technology clusters in Howard County, we cannot neglect to take the greater regional context into account. In order to accomplish this, we acquired Longitudinal Employer-Household Data (LEHD), which was provided by the United States Census Bureau. This data describes the number of jobs in different industry sectors within the State of Maryland, categorized by NAICS code. The following spatial analysis was created by using ESRIs geoinformation software ArcMap. The point data representing the amount of jobs in different industry sectors was joined to census block group polygons, in order to perform a spatial Hot Spot analysis. Depending on the input value, that is, the attribute describing the amount of jobs in each respective industry sector, a mathematical calculation using the GiBin coefficient was performed. The results of this analysis can be viewed below.

The LEHD maps illustrate the hot spots based on the amount of jobs in specific sectors within the state of Maryland. In terms of the Information sector, Professional, Technical and Services, Manufacturing as well as Real Estate, Rental and Leasing, hot spots are located in the Columbia area of Howard County. Thus, taking the results presented by the spatial hot spot analysis into consideration, one can conclude that the Columbia area is an important regional stronghold for these types of industries. Compared to the rest of the state, there are few locations that consistently achieve similar good results.

Placed-Based strategy location analysis

As part of our analysis of Howard County we performed a spatial analysis in order to pinpoint spatial locations for placed-based strategies. This was done by identifying clusters of innovative companies using the ESRI ArcMap program. To begin this process the innovative companies from the dataset used for the network analysis that were located in Howard County were geocoded into a point shapefile. Afterwards a kernel density analysis was done on the company point shapefile to determine if any clusters of companies existed. This output can be seen in Figure X. Once the three cluster locations were identified Columbia mall/Columbia Downtown, Route 100/Route 108, and Southern Snowden River Parkway an evaluation was undertaken on each to determine the suitability of the site for an innovation district and other place based strategies. This evaluation was done by looking at the current conditions and the mix of companies. This included looking at the current land uses, what is planned for the areas, and any other opportunities that were available. The Columbia Mall/Columbia Downtown area was ruled out as a possible location to focus strategies because it was already well built out and had a plan in place for its future development. The Route 100/Route 108 location was ruled out due to its difficult location for making any infrastructure changes because of the surrounding residential areas. The Southern Snowden River Parkway site is mainly comprised of industrial and commercial uses and has opportunities for cheap warehousing space and connections to future transportation projects. Based on this information we chose the Southern Snowden River Parkway site to focus our place-based strategies on.

Snowden River Parkway Innovation District

The results of our spatial analysis of innovative companies located in Howard County resulted in four main clusters. The four clusters are located around the Columbia Mall and downtown area, the area north of Snowden River Parkway and east of Route 175, the area in between Route 100 and Route 108, and the area south of Snowden River Parkway. Of the four clusters, the area south of Snowden River Parkway has the most potential and opportunity for an established innovation district in Howard County. Establishing a district with specific geographic boundaries can help the county create an innovative ecosystem that can further attract more businesses and startups to the area. The area south of Snowden River Parkway will be a physically challenging site for an innovation district but with strategic planning it can prove to be a successful place for businesses. Below we discuss the areas land values, infrastructure, walkability, existing businesses, and give detailed parcel information on each innovative company located within the proposed district boundaries (see table 1 below). We will also address some of the challenges in this area and provide examples and models of other innovation districts in other parts of the U.S.

Snowden River Parkway Innovation District: Land Value, Infrastructure & Walkability

The total area is 2,482 acres. The buildings within the area cover 315.61 acres and 530.81 acres are paved parking lots. Within the area defined as the Southern Snowden River Parkway innovation district, 1,168 acres are industrial land uses, 1,061 acres are commercial land uses, and a small percentage is residential, primarily townhomes. The zones present are Manufacturing: Light (M-1) and New Town (NT). The average land value is $432,872 per acre for the properties housing innovative companies. Although industrial land use and zoning has been decreasing in Howard County and the larger region, land near this potential innovation still has appropriate zoning for manufacturing and light industrial and is competitively priced compared to other areas. The average land value per acre is $241,772 for properties in M-1 zones in the County. The demand for these properties indicates that companies will pay a higher price to be in the Columbia area.

There is also an apparent need for economic incentive and affordable warehouse space to provide the opportunity for innovative startup companies to enter the market and grow their company in Howard Countys most innovate area, when they may not otherwise be able to do so.

According to Walk Score, this area is car-dependent which represents a challenge in fostering a district with high level of face to face contact. However, there is room for improvement in the area through the creation of amenities and cultural destinations such as restaurants, shopping, parks, and public space. Doing so will increase walkability in the area which will result in more face to face interactions. The area is also lacking in access to groceries, parks, schools, and culture & entertainment locations.

Existing Innovative Businesses

There are thirteen technologically innovative businesses in this district: ACELL Inc., Advanced Technology & Research Corporation, Envieta Systems LLC, Masstech, Osiris Therapeutics Inc., Science & Engineering Services Inc., Next Century Corporation, Bowles Fluidics, Ibiquity Digital Corporation, Raba Equity Partners LLC, and Universities Space Research Association. Using the NodeXL software, each company was grouped based on their ties to one another. While most companies were grouped into a Defense and Security group, Osiris Therapeutics Inc. and ACELL Inc. are in a Regenerative Medicine cluster group. Additionally, Raba Equity Partners LLC and Ibiquity Digital Corporation were grouped in the Telecom, networks, and cyber technology cluster.

Osiris Therapeutics Inc. has high betweenness centrality, closeness centrality, eigenvector centrality, and page rank. ACELL Inc. is also towards the higher end in terms of closeness centrality. This indicates that these businesses may be key for leveraging connections and resources with other businesses. Table 1 below outlines more detail about each of these companies including the property owner, land value, acres, 2015 property taxes, and the zone.

Company	Property Owner	Land Value	Assessed Value	Acres	2015 Property Tax (rate 1.014)	Zone
Science & Engineering Services Inc	AAK LLC	$7,187,400	$13,509,133	15	$202,048	M-1
Universities Space Research	Universities Space Research	$4,039,300	$10,779,867	8.43	$101,223	M-1
Masstech	GATEWAY CROSSING 95 LLC	$3,938,600	$6,357,500	8.22	$95,663	M-1
ACELL	6711 GATEWAY LLC	$3,061,800	$14,733,333	6.39	$208,669	M-1
Advanced Technology & Research Corp	GATEWAY A 74 & A 76 LLC	$22,650,100	$42,000,000	115.55	$667,125	M-1
Envieta LLC	MOR GATE LLC	$5,122,200	$13,382,000	10.69	$194,804	M-1
Osiris Therapeutics	EM CORP UNIVERSITY OF MD MEDICAL	$2,467,600	$7,417,400	5.15	$10,979	M-1
Agnik LLC	MERRITT-CCP II LLC	$2,607,000	$11,685,067	6.65	$167,885	NT
Martek Biosciences Corp.	COLUMBIA BUSINESS CENTER GREEN LLC	$844,100	$4,021,300	3.23	$59,344.70	NT
Raba Equity Partners LLC	MERRITT CCP III LLC	$3,014,700	$19,317,200	7.69	$275,305.93	NT
Ibiquity Digital Corp.	MERRITT CCP V LLC	$2,211,100	$14,955,067	5.64	$212,784.35	NT
Bowles Fluidics Corp.	BROADSTONE BFC MARYLAND LLC	$1,633,500	$5,291,167	6.25	$79,123.92	NT
Next Century Corp.	AAK II LLCMARYLAND LLC	$9,516,100	$21,492,633	19.86	$317,872.89	M-1

Table 1. Southern Snowden River Parkway Innovative Company List

Land Use Category	Acres	Percent
Industrial Land Use	1154.27	47%
Residential	238.4	10%
Commercial	690.62	28%
Exempt	382.63	16%
Total	2465.92	100%

Table 2: Land Uses Within Innovation District

Industrial Land Use	Acres	Percent
Office Building	674.58	29%
Warehouse	475.896	41%
Restaurant	7.037	1%
Retail	29.33	3%
Entertainment	8.99	1%
Other Industrial	303.99	26%
TOTAL	1167.95	100%

Table 3: Industrial Land Uses within the proposed innovation district

Commercial Land Use	Acres	Percent
Office	673.04	63%
Warehouse	66.83	6%
Restaurant	11.17	1%
Retail	66.20	6%
Other Commercial	244.08	23%
Total	1061.32	100%

Table 4: Commercial Land Uses within the proposed innovation district

Creating an Innovation District

In addition to economic assets, successful innovation districts have three types of physical assets: public, private, and connective. Economic assets are the innovative companies within the district that fall into a subset of industries, including research-oriented sectors and specialized, light manufacturing (Katz & Wagner, 2014). An integral part of identifying areas with potential for an innovation district is finding an area with a concentration of businesses within the defined sectors. Several strategies of spatial analysis have been performed to find suitable areas with a concentration of the innovating businesses analyzed. After identifying the anchor institutions and the geographic boundaries of the area designated for implementation of this strategy, recommendations for encouraging growth can focus on the physical assets needed in the area.

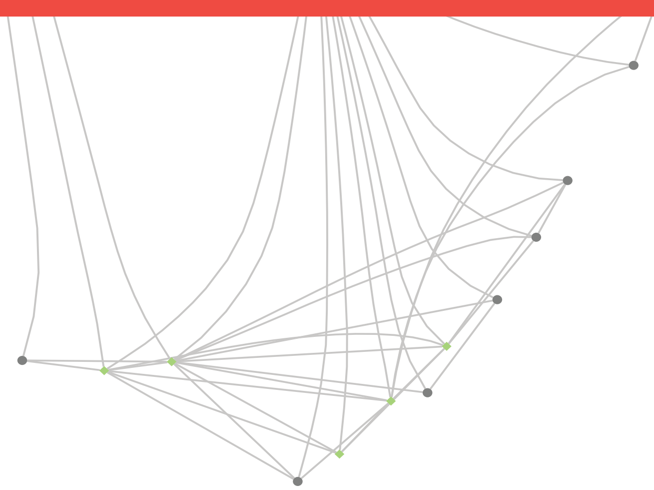
Physical assets of effective innovation districts include those that are public, private, and physical assets that bring the disparate parts of the district together or connect it to the wider region. Public physical assets are spaces that facilitate interaction and provide space for informal meeting and collaboration. The design of the infrastructure within an innovation district should help connect the inventors and entrepreneurs working within it. Because of the nature of innovation districts, assets in the public realm are generally created to work with the high-tech tools used by industry professionals and encourage networking. Physical assets may also be housed in privately owned buildings.

Private physical assets fill a need, such as neighborhood retail and flex work space or lab space. They may also take the form of a specific design tactic, such as floor layouts that encourage interaction and encounters. The value of physical assets like this has been underscored because individuals, not groups or leaders, will be the ones that must form linkages and do the work needed to create effective partnerships. This knowledge was the basis for the design of Pixar s office and many other innovative and successful companies that stress the importance of networking (Hwang & Horowitz, 2012, p. 206).

Physical assets that connect the district to the larger area are important to prevent the innovation district from becoming an island within its larger context. These strategies may include providing regional transit access or the extension of broadband access to the surrounding neighborhoods.

Chapter 7

Innovation Network Analysis



As has been discussed in The Nature of Innovation section, innovation may be thought of as a series of activities, [list research, invention, proof of concept, commercialization and refer to the figure] ranging from research to invention to commercialization and everything in between. Social network models are being used to investigate the social structures and dynamics that occur within these activities. Network models are comprised of nodes representing people and organizations involved in innovation, and lines (also called ties or edges). Nodes typically represent people but can also represent organizations and places. Ties represent a relationship between nodes and identify opportunities for future innovation based on patterns.

We use U.S. patent data, SBIR grant data, STTR grant data, and publication counts to model innovation social networks, or innovation networks. Below are detailed descriptions of how nodes, edges, and ties model innovation.

Nodes, also known as vertices, are points on a social network graph that represent individuals, organizations or places. Each node is assigned attribute data that allows them to be connected with ties. Ties connect individuals and organizations with all other individuals and organizations they have collaborated with. Places are connected with all organizations and people who have worked in that jurisdiction.

Edges can be described as links or ties that form relationships between two nodes. These relationships formed, represent network proximity, association, investment, trade, hyperlinking, and citation (Hansen, Shneiderman & Smith, 2011). By utilizing the graph theory method to represent the aforementioned connections, edges can be examined by the connection type as well as the connection strength. The connection type, describes whether the edge is directed or undirected. Directed edges, show a clear connection between the nodes origins/destinations and are displayed as lines with arrows pointing to the specific nodes (Hansen, Shneiderman & Smith, 2011). Characteristically, these types of edges may or may not be reciprocated (Hansen, Shneiderman & Smith, 2011). Alternatively, undirected edges do not display a clear connection between a node s origin and destination and are displayed as lines attached to nodes with no arrows. However, these edges cannot exist unless reciprocated (Hansen, Shneiderman & Smith, 2011). The connection strength, is defined as either weighted or unweighted. Weighted edges include variables that delineate whether the edge connecting nodes exhibits a strong or weak tie and will be displayed as a thin or thick line weight depending on its connection strength. Unweighted edges only indicate that an edge exists and are displayed as thin lines (Hansen, Shneiderman & Smith, 2011).

In terms of social network analysis, ties strength indicates the type of relation between two nodes. In other words, examining the strengths between ties engages the viewer to understand the closeness and extend of the relationship that exists between different nodes. This strength can persists as strong or weak. In social network analysis, strong ties between nodes or edges signify friendly and interactive relationships amongst the specified fields or industry sectors. On the other hand, weak ties signal less interaction and collaboration between the connected nodes or edges. Hence, both strong and weak ties lend the possibility for potential connection in the future amongst and between these fields of common interests. To explore the topic of tie strength more, an example displays the interaction of strong and weak ties with nodes. For instance, nodes connected by weak ties generally imply the nodes work with similar technology, while nodes connected by strong ties usually imply the nodes work together on particular projects. Thus, weak ties express the product creation type whereas strong ties specify those working together on a given project.

Network Metrics

One of the benefits of analyzing networks is the ability to interpret them both visually and numerically. While useful for some types of analysis, metrics are not always needed to successfully interpret a network. However, understanding the ways in which networks are measured can help explain inter-network relationships and the roles different actors play within a network.

Network metrics can be calculated for either specific vertices or overall graphs. Vertex-specific metrics represent a scaled-down network for each actor, sometimes called an ego network. Overall or aggregate graph metrics, are useful for comparing multiple networks, or observing one network over time. They are best able to demonstrate a community s level of connectedness in a relative sense. Individual metrics such as betweenness centrality can be used to identify the role or importance of an actor in the network and make intra-network comparisons. The concept of connection is central to social network analysis. Understanding the number, type, and strength of various connections is critical to understanding the patterns of idea flow within a network. This, in turn, is the first step in learning to manage this flow effectively (Pentland, 2014). Network metrics describe how connections can lead to relationships and interactions. There are numerous network metrics that can be calculated; while some are described here, a full glossary is available in the Appendix [X].

Vertex-specific metrics can be used to compare actors within a single network; these are largely measures of centrality. The most basic of these measures is degree, also known as degree centrality. Degree centrality is the measure of how many unique connections, or edges, emanate from one node, or vertex (Hansen, Shneiderman & Smith, 2010). These unique connections can be either directional or non-directional. Directional relationships are measured in in-degrees (the number of edges that are pointing towards the vertex, or the number of connections that have been offered to that vertex) and the number of out-degrees (the number of edges pointing away from the vertex, e.g. the number of connections that are initiated by the vertex). The higher the degree centrality, the more connections an individual or organization has.

Another measure of centrality is betweenness centrality. This is best understood as a measure of that node s ability to function as a bridge between other individuals. High betweenness centrality indicates a node s importance in keeping others connected to the larger network; if that node is removed, its connected nodes will be disconnected from the network as well. Nodes with high betweenness centrality act as brokers, facilitating communication and relationships within a network; they are also analogous to keystone species in an ecosystem as described in The Rainforest (Hwang and Horowitt, 2012).

Closeness centrality measures average shortest distance from each node to every other node (or vertex). This can be considered a measure of density. The closer a node s closeness centrality is to 1 (the lowest possible value), the more central role that individual node plays in a network (Hansen, Shneiderman & Smith, 2010).

Finally, eigenvector centrality is a compound metric that considers both the degree of an individual vertex and the degree of the other vertices it is connected to. It relates to the idea of popularity, measuring not just a vertex s degree, but the value of its connections. If a vertex is connected to other vertices with high degrees (more popular actors), that connection expands the vertex s network more than a connection to a vertex with few other connections (unpopular actors), and is therefore more valuable. The more well-connected vertices a certain vertex is connected to, the higher its eigenvector centrality will be.

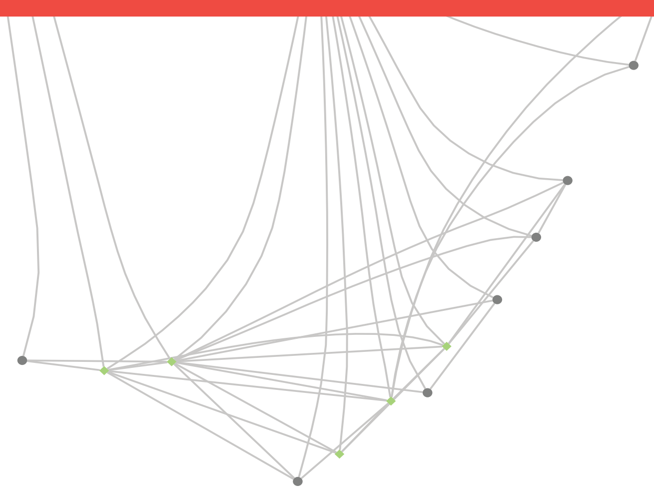
The clustering coefficient measures how connected a vertexs connections are to one another. Mathematically, it is the number of edges connecting a vertexs neighbors divided by the total number of possible edges (Hansen, Shneiderman & Smith, 2010). This represents how well-connected the actors near a certain vertex are, but do not necessarily describe the vertex itself.

Overall graph metrics can be used to compare networks, or to observe change in a network over time. Graph density is a metric between 0 and 1 that indicates how interconnected the network vertices are; in a basic sense, this is the number of existing edges divided by the maximum number of possible edges. Some basic measures include graph type, which indicates whether a graph is undirected or directed (whether relationships are reciprocal or not), vertices, the total number of actors in the network, total edges, the total number of connections (also calculated are the total number of unique and duplicated edges). Measurement of connected components indicates the amount of groups in the network, or clusters of vertices that are connected to one another but not to the larger network. Geodesic distance indicates the length of the shortest path between two vertices. The unit is an edge, so the geodesic distance between two vertices with one vertex in between them would be two. In looking at the overall network, maximum geodesic distance (longest possible distance in the network) and average geodesic distance are commonly calculated (Hansen, Shneiderman & Smith, 2010).

Network analysis software allows for easy calculation and analysis of these metrics. Vertices can be sorted to find individuals with high betweenness centrality or high Eigenvector centrality who anchor the network. Network metrics are best understood in relation to network visualizations, where they can be graphically displayed and their relationships analyzed.

Chapter 8

Network Visualization



Visualizing networks plays an important role in presenting innovation networks and can help connect businesses and people in a more efficient way. Over time, several techniques for network data visualization have been developed in order to tap into this economic development resource. Network visualization is derived from fundamental graph theory and addresses its basic structural properties (Chen & Yang, 2010): Node degree: Number of edges attached to that node Node density: Mathematical formulas calculate individual density Path length: Number of edges in the sequence that a walk follows Component size: Counted by the number of connected nodes in a graph

Graph representations of networks As described, network graph consists of a set of vertices joined by edges. Vertices are most often depicted as points in a plane connected by edges as straight or curved line segments (Fruchterman and Reingold, 1991). Graphs can be either directed or undirected. Undirected graphs are the most general class and do not rely on the direction of interaction. This makes them simpler to create and understand compared to directed graphs, in which the degree and direction of interaction is displayed through the format of edges between nodes (Eades and Xuemin, 1989).

Visualization of big data sets: Transforming big data sets into visually appealing graphs is a specific challenge that is addressed by various literature. Special techniques have to be applied in order for the viewer to make sense of the great amount of nodes and edges that are shown per area. According to Ben Shneiderman, the design of large graphs should follow the principle of overview, filter and zoom, details on demand . Due to the high number of nodes, it is necessary to format the graph in a way the presented information can be processed by the human eye. Thus, the different graph elements have to be visually represented in a way that their importance can be understood. For instance, colour or line thickness can be used to allow a multivariate decoration of the graph structure (Unwin, Theus & Hofmann, 2006).

For adequate presentation of big data graphs, they have to be specified beforehand: What are the important links? What is their data connection? How should it be drawn? Depending on the answer to such questions, specific layout algorithms can be chosen.

Layout algorithms Due to the great variety of different information structures, there is no single visualization method that can appropriately represent all kinds of information structures. One of the most straightforward ways to display network graphs is the node-edge layout, which helps users to clearly recognize the structure of the social network. This layout form in turn, can be further separated into three different kinds of layouts: Random layout, force-directed layout and tree layout. The random layout is placed at different locations in the graph and thus not as visually clear, specifically for large networks. As already indicated by the name, a tree layout chooses one node as the tree root and its connected nodes become the children of that root node. Its structural, hierarchical layout makes the tree layout easy to understand. The force-directed layout is also known as a spring layout. It displays the graph as a virtual physical system. However, it involves high cost due to its running time and is therefore not suitable for large network datasets (data techniques) (Chen & Yang, 2010).

Several common undirected layout algorithms are Fruchterman-Reingold, Kamada and Kawai, and Davidson Harel. The Fruchterman-Reingold and Kamada-Kawai algorithms are known as spring-embedded or distance scaling algorithms. These algorithms portray nodes that reject each other as disconnected and nodes that share an attraction as connected (Pfeffer). The Fruchterman-Reingold algorithm uses three steps for each iteration: calculate the effect of attractive forces on each vertex, then calculate the effect of repulsive forces, and finally limit the total displacement by the temperature. One of the benefits of this algorithm is that it is relatively quick to render due to its emphasis on speed and simplicity (Fruchterman and Reingold, 1991). One potential disadvantage of this algorithm may be that multiple layouts of the same network will not look the same due to the local optimization approach. Aesthetic criteria Most basic criteria, when it comes to the aesthetic design criteria of network graphs, include minimizing the number of crossings as well as total drawing area and maximizing symmetries. To be more specific, one can divide essential criteria into three groups: General Criteria: Reduction of visual clutter, spatial misunderstanding resulting from spatial closeness, maximizing space efficiency and spatial matching of items Dynamic Graph Criteria: Maximization of display stability, reducing cognitive load when interpreting presented data Aesthetic Scalability Criteria: Graph readability, scalability in number of vertices and edges

Fleischer and Hirsch outline strategies that can be applied to fulfill the given criteria. These include bend minimization, which makes graphs more understandable by creating easier to follow edges. Area minimization uses the available space efficiently while satisfying a general aesthetics criterion of filling a space with homogeneous density. Angle maximization, keeping edges at a distance from one another, is important for displaying graphs on screens with low resolution. Symmetries and clustering in graphs, if present, should also be displayed as this helps to reveal the graph s structure (Fleischer and Hirsch, 1998, p. 19-20). Fulfilling the presented criteria does not necessarily result in a good layout, as this is usually dependant on the quality of the data as well as the desired visual outcome of the task at hand. Therefore, more than one layout algorithm is needed to result into a cohesive as well as understandable network graph (Landesberger et al., 2011).

Communicating with network graphs

A network graph should communicate to its audience how the groups are structured and what the most important nodes are. The different visual elements of a network can provide this information in several different ways. According to Mackinlay, position is the most important design element for communicating the structure of the network and any quantitative, nominal, or ordinal attribute of a node (1986, p. 125). However, the use of additional visual elements can provide greater detail. For nominal, or categorical, data, the most effective ways to communicate include density, color saturation, color hue, and texture. Attributes of nodes can also be further specified by the use of different shapes and sizes (McFarland and Bender-deMoll, 2006; Mackinlay, 1986, p. 125). Eventually, how the graph is designed will determine how effectively the underlying data can be understood and used for visualizing the analysis.

This report features novel analyses of innovation networks. These networks are comprised primarily of the people and organizations involved in innovation and the connections they share through those innovation activities. Science, Technology and Innovation (STI or herein simply innovation) is a process comprised of several different types of activities including research, invention, proof-of-concept, commercialization, and diffusion. These activities are carried out by people in various roles researchers, inventors and entrepreneurs for example; and the organizations (companies, institutions, agencies, etc.) that they are connected to. Other people and organizations in the network may be involved in supporting roles

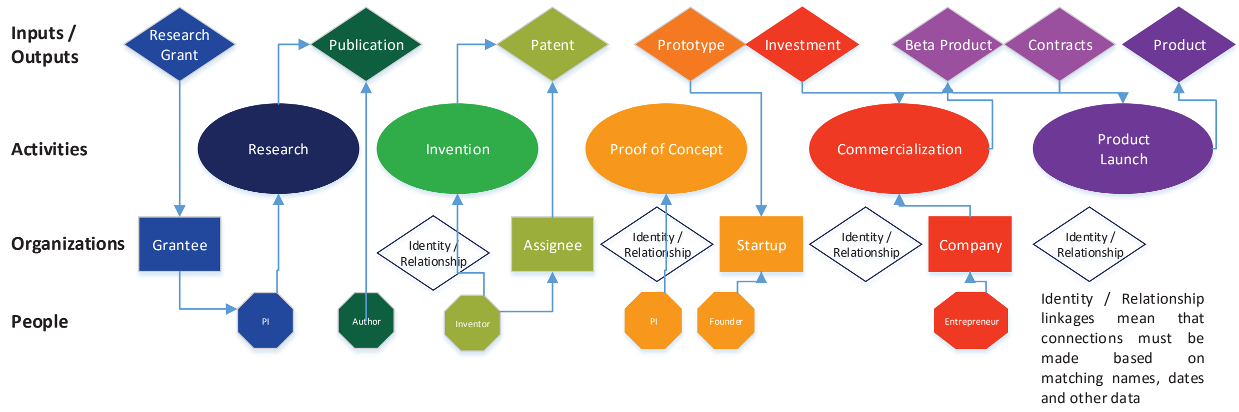


Figure 8.1

providing funding, resources, ideas, know-how or social capital that helps the innovation process advance. In the network models people are represented as nodes or vertices, and are connected to each other by lines (called ties or edges) representing the relationships connecting them. The various activities produce both tangible and intangible outputs including publications, intellectual property (IP), startups, prototypes and products. Figure 1 shows a representation of innovation activities along with inputs and outputs. These outputs may be connected to each other (and to certain inputs) through citation relationships. For example a patent (IP) may cite publications describing concepts important to the patent; or a journal article (publication) may cite a research grant (input) that supported the research. These products of innovation activities are also connected to the people and organizations involved through author, inventor, founder and ownership ties.

Another important set of relationships (what we call a relation in network terminology) is location. People and organizations are associated with specific places where they live, work and engage in various innovation activities. In many cases people and organizations are associated with multiple places, making it difficult to assign a single location attribute to them. To resolve this we include places as nodes or vertices in the network. The locations of people and organizations involved in innovation activities are then represented by ties to those place nodes.

In theory, given perfect knowledge of every activity and relationship (and unlimited computing power), a complete innovation network representation could be constructed. However in reality many if not most innovation activities are undocumented or proprietary. Nevertheless, robust partial network models may be constructed from available data sources. While incomplete, these models are remarkable in what they reveal about the structure of the innovation ecosystem. By layering multiple data sources and relations we are able to construct useful models of the core of that ecosystem. Since network models are inherently open, additional data may be added at any time. Thus the network models that we produce are base models which users may continue to refine over time with additional data. A listing of data sources including both base model and potential sources is shown in table 1.

To construct our network model from these data sources it is useful to think of each inno-

Data Sources

Innovation *Activities:* Many if not most innovation activities are not documented
(research, discovery, invention, development & commercialization of new or improved products and services)

Innovation *Events:* Documented milestones in the innovation process

	Administrative Data				Big Data	
Sources of Data for Network & Temporal Analysis	Administrative Records	Direct / Indirect Data	Primary Data Collection	Citations	Publications	Social Media
	Patent Data • Applications • Grants • Assignments	**Open Source** • CrunchBase (→ $$) • AngelList	**Organizational Structure** • Universities • Companies • Regions / governance	**Patent Cites** • Patent chain • Other cites	**Journal Publications** • Coauthoring • Institutional • Publication	**Twitter**
	NIH • Projects (funded research) • Abstracts • Related docs / patents	**Reference / Research Data** • Universities + consortia • Federal Labs • NBER, BEA, BLS, Census	**Collaborations** • Project-based networks • Formal / informal support networks	**Journal Cites** • Citation chains • Coauthoring • Institutional	**Other Scholarly Pubs** • Coauthoring • Institutional • Publication • Scholarly reports	**LinkedIn**
	NSF / NASA • Projects (funded research) • NASA / NSF source • NSF only source	**Proprietary** • D & B, Hoovers, Mfg News • Implan, REMI • ThomasNet.com	**Accelerators / Incubators** • Internal networks • Inter-organizational networks	**Other Cites** • Books • Web • General media • Subscription networks	**Web / General** • Blogs • General pubs • Op-Eds • Professional reports	**ListServ networks**
	SBIR / STTR • Projects (funded research) • Phase I / II • Company Profiles	**University Research** • Sponsored research • Licensing	other			**Academia.edu**
	Other / pending sources • STAR METRICS • WIPO / IPC • NIST	**Intermediaries** • Economic Dev. Orgs • Professional Associations • Conferences	other			**Other social media**

Table 8.1

vation activity in terms of an activity network comprised of the people, organizations, places and documents (outputs) associated with that activity. The information necessary to model these activity networks may be extracted from individual documents or records in our data sources. By themselves activity networks are not very interesting or useful. However when all of the activity networks are aggregated together they form more complex networks through shared nodes and overlapping connections. The process of extracting activity networks from source documents and then combining them into larger product or innovation networks is depicted in figure 2.

Once the larger innovation network is assembled we use network analysis software (in this case NodeXL) to identify specific subnetworks called connected components. Connected components are subgraphs in which every node is connected to every other node by a path, and are not connected to any other nodes in the supergraph (complete network). In many cases connected components end up being the networks of individual companies. In other cases the connected components may reveal organizations that are connected to each other through collaboration or through shared people. These cases may also represent merger and acquisition activity, or they may represent funding or ownership ties. Whatever the reason, connected components with more than one organization should be investigated further to determine the reason(s).

Using NodeXL we may group vertices by connected component then represent the network using the group-in-a-box layout which presents each connected component in a separate box. The largest component is always in the upper left corner and the smallest is always in

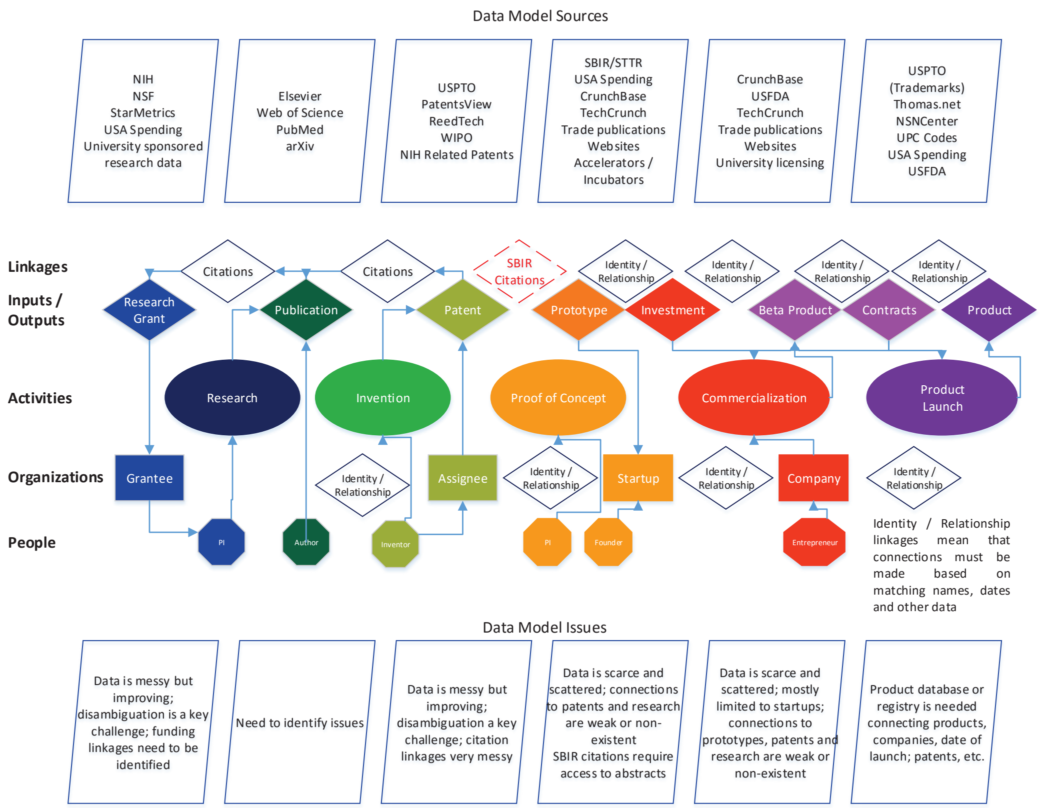


figure 8.2

the lower right corner of the graph. As will be discussed later, this arrangement ends up providing a useful organizing structure for targeting economic development strategies based on the size, complexity and stage of development of the components.

While connected components are useful in revealing organizational structures they are primarily descriptive. Industry cluster theory is based on the defining idea that clusters involve networks of organizations and people that are connected through collaborative and competitive relationships. For example firms may be connected through supply chain relationships, or they may be competitors in the same market, drawing from the same labor pool. Organizations may also be connected to each other as (actual or potential) collaborators or competitors in terms of innovation. While we often do not have data on actual cluster relationships we can model potential relationships that may then be verified by economic developers in the field.

To do this we introduce a new relation (technology clusters) involving a new type of tie (weak ties) between our existing people and organization vertices. Weak ties may be thought of as potential ties based on mutual connection to a third node. In this case that third node is a technology classification for example patent classifications, keywords, topics and the like that describe a specific technology field. These classifications may be extracted or derived from the individual source documents. Documents with similar technology classifications would be weakly connected, thus generating weak ties between their respective organizations and people. Data Sources and Network Relations included in this report The networks modeled and analyzed for this report included data from the following sources: 7 Patents USPTO 7 Research Grants NIH, NSF, NASA 7 Proof-of-Concept / Commercialization Grants: SBIR/STTR Phase I and Phase II Data sources under development / available for inclusion include the following: 7 TEDCO Stem Cell fund; other TEDCO funding 7 University of Maryland, College Park sponsored research & licensing data 7 CrunchBase data See table 1 for a full list of available / potential data sources.

Records were extracted from the listed data sources according to the following criteria:

Record date between 1/1/2010 and 7/30/2015 (application date for patents; award date orcontract start date for all others.

Records in which any party listed on the document other than federal government agencies had an associated location in Howard County, MD; or any records associated with Maryland research universities (primarily Johns Hopkins and member institutions in the University System of Maryland including University of Maryland College Park, University of Maryland Baltimore, and University of Maryland Baltimore County, among others).

Names were matched across all data sources. Variants of the same name were collapsed into a single label for matching and network purposes.

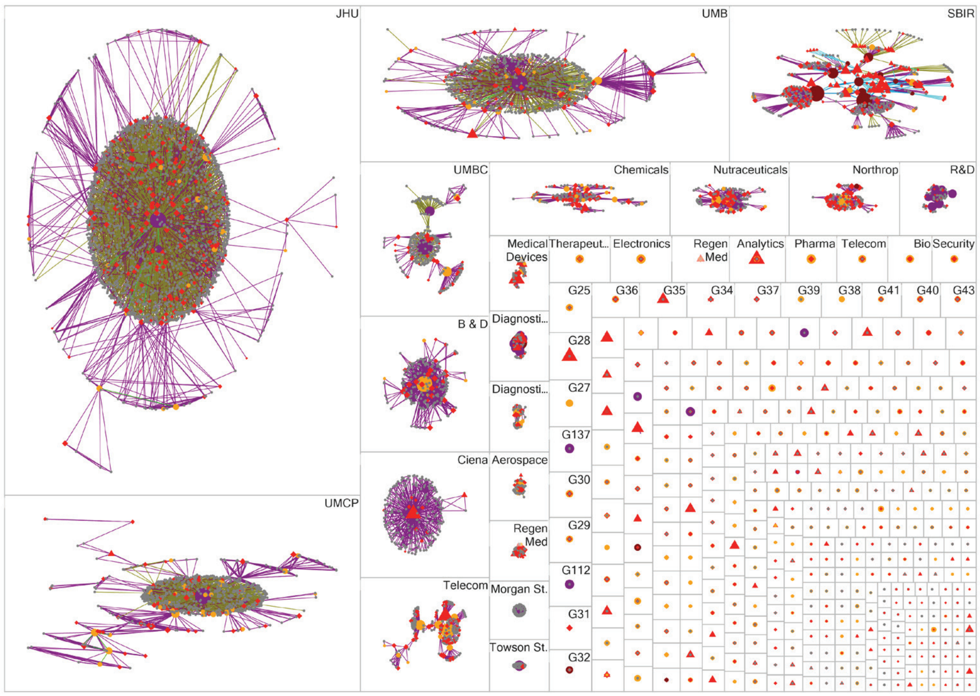
Relations included research & patenting, location, and technology-based weak ties based on patent classifications. Network Characteristics For the network using the data sources listed above the network includes 8,175 vertices and 23,497 ties (edges) for the research/invention and patent-based technology ties combined. The location relation includes 857 place vertices and 6,295 location ties. The research group is comprised of four university components accounting for about 51% of all vertices and 35% of all edges. The industry group is comprised of 362 connected components accounting for about 48% of all vertices and 59% of all edges. The remaining vertices (about 1%) and ties (17%) are un-clustered and are predominantly federal government agencies and funding or patent ties between those agencies and clustered vertices.

Technology-based weak ties for this network are based only on patenting in the same class and subclass, and are only shown between patent assignees. There are 541 such ties in this network. Additional technology-based weak ties could be added based on keywords and/or full-text search comparisons of patent and research grant abstracts. Identifying Technology Clusters Technology clusters are groups of connected components that are connected by technology-based weak ties.

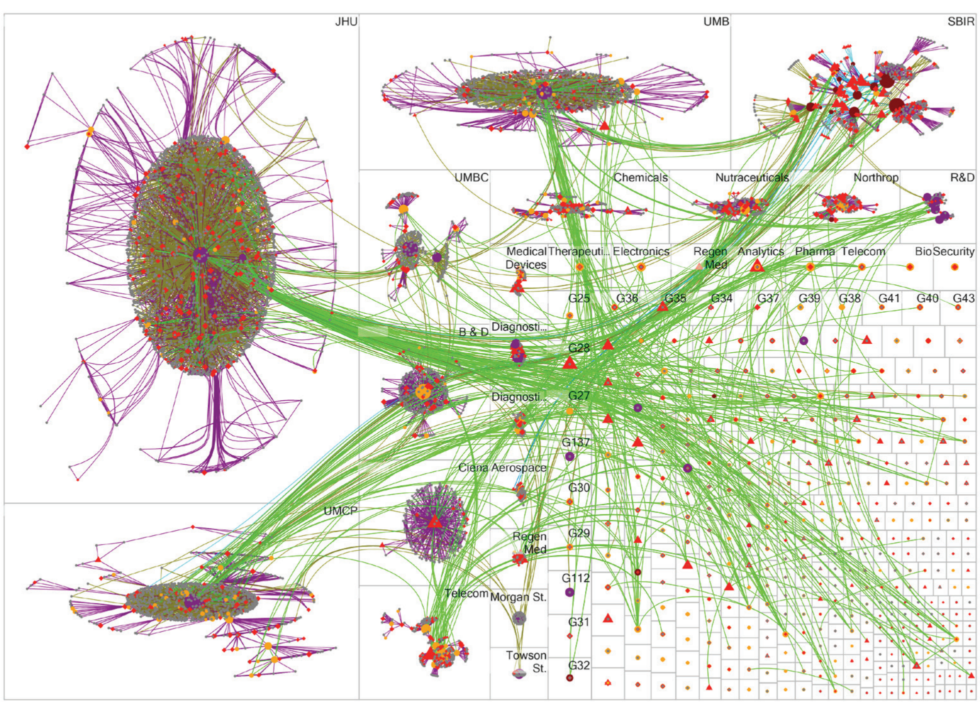
Interpreting the Network Models

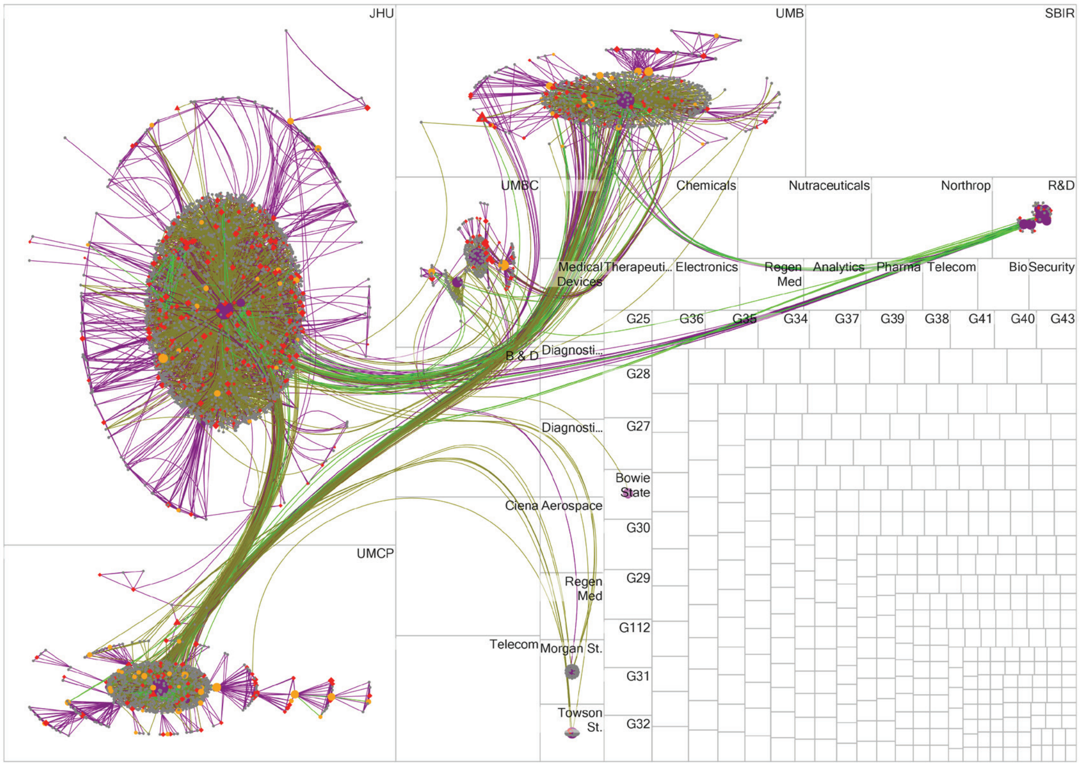
The network models developed for this studio are interactive NodeXL files (included in final package) and are most useful when used interactively. The network images that follow are useful for illustrating the overarching structure of the models and certain key findings. With over 8,000 vertices and 23,000 edges there is no one image that will adequately represent the networks. Images that capture the whole network do not show complete detail, while detailed cluster images necessarily exclude much of the network to focus on the clusters. Images that show the entire network, especially those that show weak ties may appear overwhelming. However conveying the idea that while the innovation network IS large and complex, there is also some organizing structure to it is an important message. Many people do not fully appreciate either the complexity or the structure of innovation activities in their own communities. Network images 1 and 2 are intended to facilitate that appreciation.

Components along the left and top of the overall network graph form a larger research cluster comprised of regional and national re-



Top: Network image 1
Bottom: Network image 2

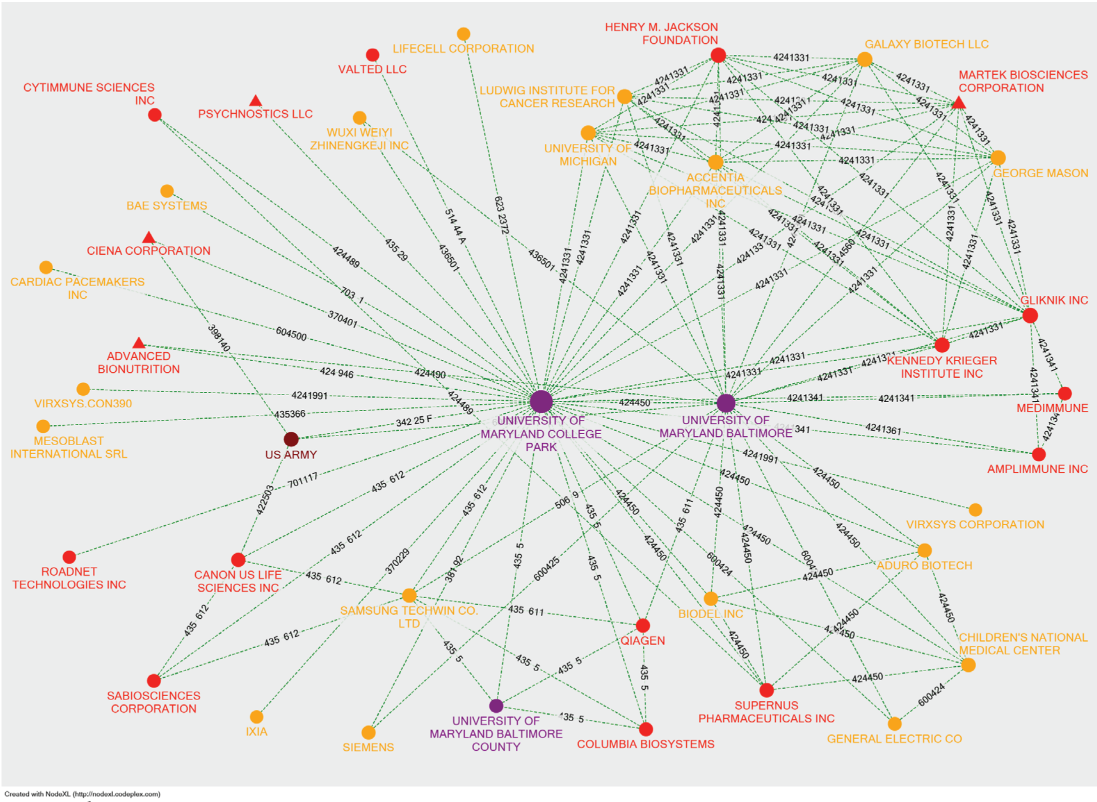




Network image 3

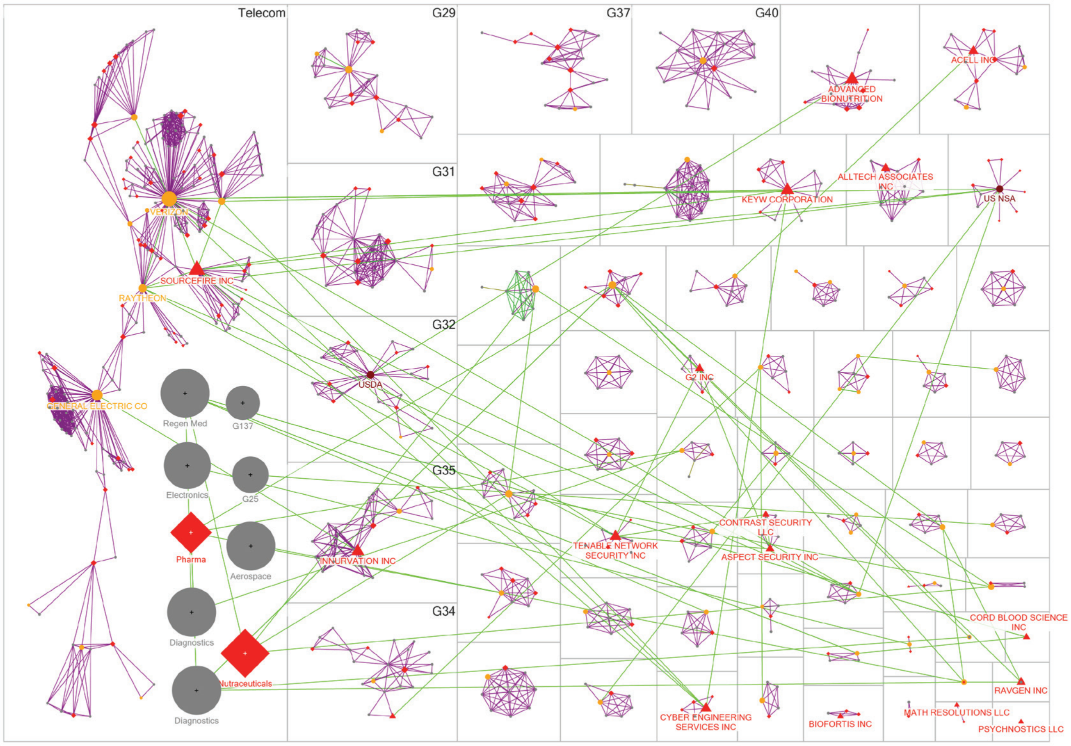
search universities and laboratories. This cluster is anchored by the regions three major research universities Johns Hopkins (including the Applied Physics Lab), University of Maryland College Park, and University of Maryland Baltimore. UMBC, UMCES, Towson, Morgan State and Bowie State universities along with a small cluster on national universities make up the rest of the research cluster.

Each cluster includes researchers and / or inventors with location ties to Howard County. One of the main challenges of innovation led economic development is translating these research efforts into startups and economic activity for Howard County. There are two ways in which the network analysis can help economic developers do this. First, each weak tie provides a specific lead where there may be potential for tech transfer or sponsored / collaborative research. In many cases these leads are between universities and companies (network image 4). In others they may be between two companies (network image 5).



Top: Network Image 4

Bottom: Network Image 5



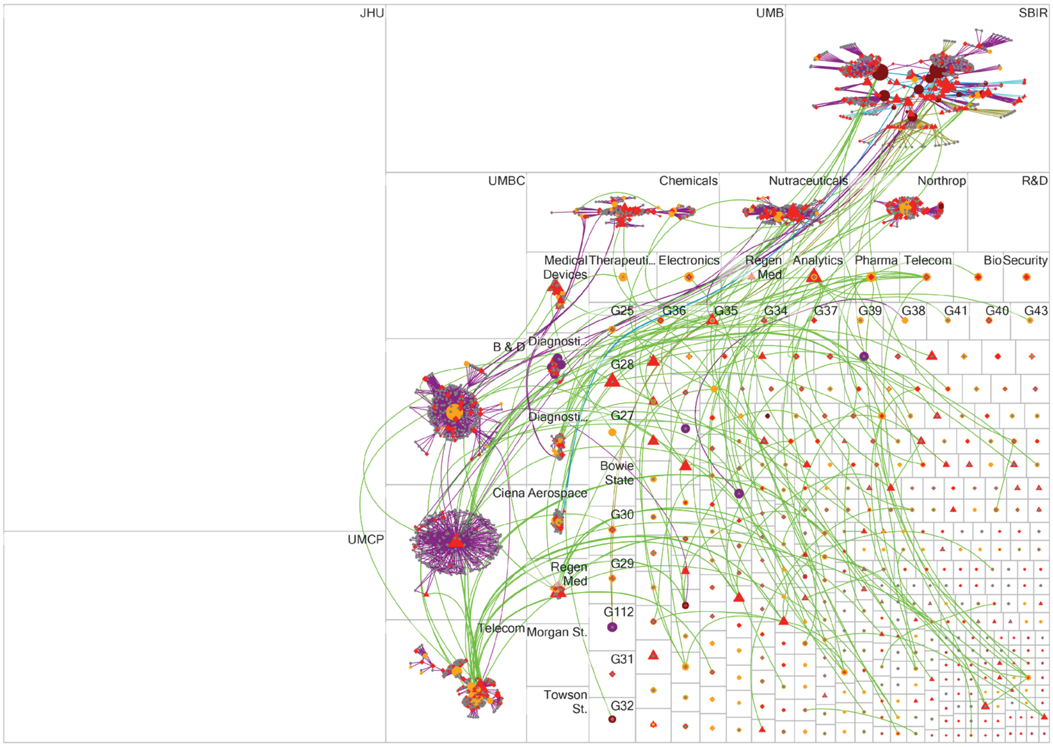
The rest of the network comprises the overall industry component, including all of the industry clusters and any un-clustered nodes. Network image 6 shows the industry component in its whole network configuration, while network image 7 shows the same groups reorganized without the research groups.

Network image 7 illustrates some of the broader organizing structure provided by the clustering algorithms and the group-in-a-box treemap layout. The largest group is located in the upper left corner of the graph, while the smallest group is located in the lower right corner. The size of the group correlates well with the size and development stage of the firms involved. This in turn means that the graph can help organize the targeting of economic development strategies. Some large groups towards the upper left of the graph are centered on large firms that are located within the region but not in Howard County (Black & Decker and Northrup Grumman, for example). These essentially represent talent clusters. Other groups are centered on Howard County based companies (Ciena, for example).

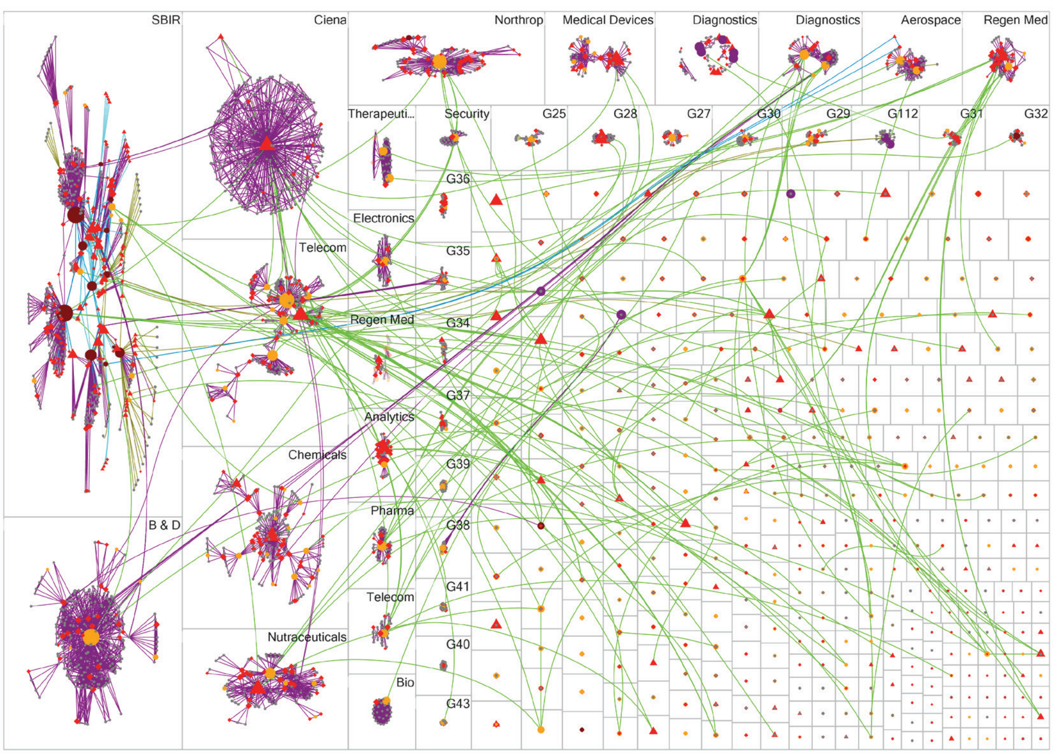
In cases like Ciena, for example, there are few or no other firms that appear engaged with the central firm in the innovation network. Further investigation is warranted to determine if this is an accurate portrayal and if so, why. From the perspective of the innovation network this pattern presents a level of risk to the County because it is easier for the firm to pick-up and relocate. It does not appear to be embedded in an innovation network that would make it harder to leave or to replicate somewhere else. The strategy for firms presenting this pattern is first further investigation to determine if there are aspects to the innovation network were undetected in this analysis. Connections to other county firms through supply chains should also be investigated. If the representation in the network analysis is accurate, the economic development strategy should follow a Business Retention and Expansion (BRE) track along with enhanced relationship building to help increase the level of embeddedness in various community networks, including innovation. This is highly individualized process for economic developers because firms may present this pattern for their own strategic reasons. Especially in this region, security and confidentiality are reasons why a firm may choose to be more isolated. If so, the risk of the firm departing is low and concern may not be warranted.

In cases like Black & Decker or Northrup Grumman where the firms present similar patterns but are located outside the County the issues are similar but a firm departure s impact on the county would be more limited to county residents who work at the firm or supporting firms. In these cases the economic development strategy should also begin with further investigation to determine risk level. After that, pursuing similar BRE strategies to those described above in partnership with neighboring economic development organizations may be appropriate.

In both cases the pattern of redevelopment following the departure of a large form suggests that while some of the creative talent relocates with the firm, a portion of that talent chooses to stay put and pursue employment with other firms in the region or to launch local startups. An economic development strategy that the County could pursue would be one of scenario planning. What if a major employer left? What would be the County s response? What programs could it implement quickly to support nascent startups or rapid reabsorption of the impacted workforce within the County? To be clear, there is nothing in the network analysis or in our other analyses to suggest that any firm especially those mentioned here by example are contemplating relocation. That was not part of our investigation. The forgoing is simply a logical interpretation of the potential risk that may accompany such network pat-



Top: Network Image 6
Bottom: Network Image 7



terns, and to suggest that further investigation by HCEDA may be warranted. Developing Keystones Local industry leaders are an essential part of the innovation ecosystem. The leaders both firms and to people behind them are referred to as keystones by Hwang and x in their book The Rainforest: (2012). Regardless of what they may be called, developing a cadre of private sector leaders who are engaged in the local innovation ecosystem is critical to maintaining and growing a healthy innovation ecosystem.

While engaging people and firms like those discussed in the previous section might be a strategy for increasing their connections to the community, the county is more likely to find and engage keystones within groups that already display more complex network structures, like the Telecom or Chemicals groups in network image 7. Often it makes sense to develop such leaders within the context of their technology clusters as discussed in a later section.

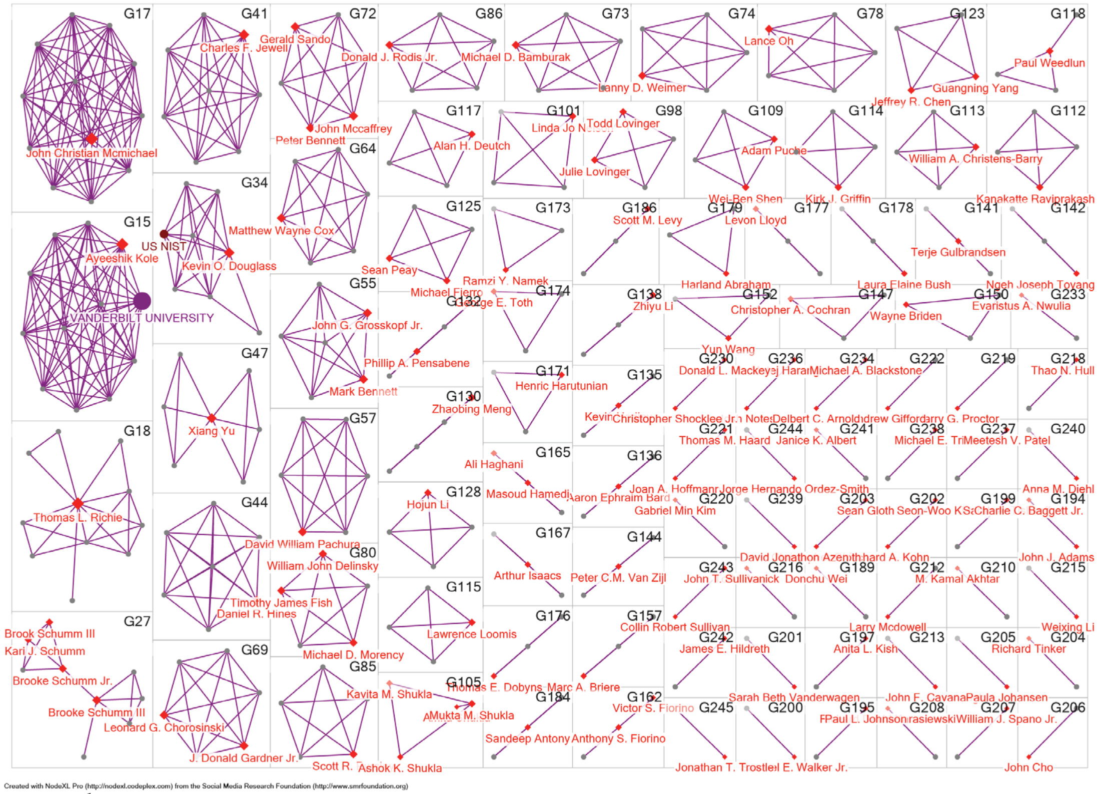
However in the context of looking at the overall innovation network (image 7), it is useful to note that because of the organizing structure imposed by the groups and layout, those prospective keystones are more likely to be found in the groups on the left side and top of the network image, since these generally represent firms and network components that are more developed, established and embedded in the community. The idea of strengthening the innovation ecosystem is more likely to be consistent with their internal corporate strategies and stage of growth. While there may be exceptions, this organizing structure at least shows economic developers where to focus their attention to begin such efforts.

Entrepreneurial and Startup Strategies Startups and entrepreneurial ventures represent the other end of the spectrum from the discussions of the foregoing sections, and in keeping with the organizing structure of the network graph, the firms and people engaged in such ventures tend to occupy the lower right corner of the innovation network graph (network image 7). New startups also have a very different set of needs and suggest a different set of economic development strategies than the firms and groups on the left side of the graph.

Such strategies include access to capital and markets, accelerators, incubators, innovation districts, access to research and specialized facilities / equipment; and several others. These have been written about extensively elsewhere and will not be discussed further here. What will be discussed further is where to focus those efforts. Network images 8 and 9 are enlarged and reorganized views of the lower right corner of the larger innovation network. Network image 8 identifies groups of people with at least one Howard County connection that are connected by one or more patent but who are not associated with a specific firm.

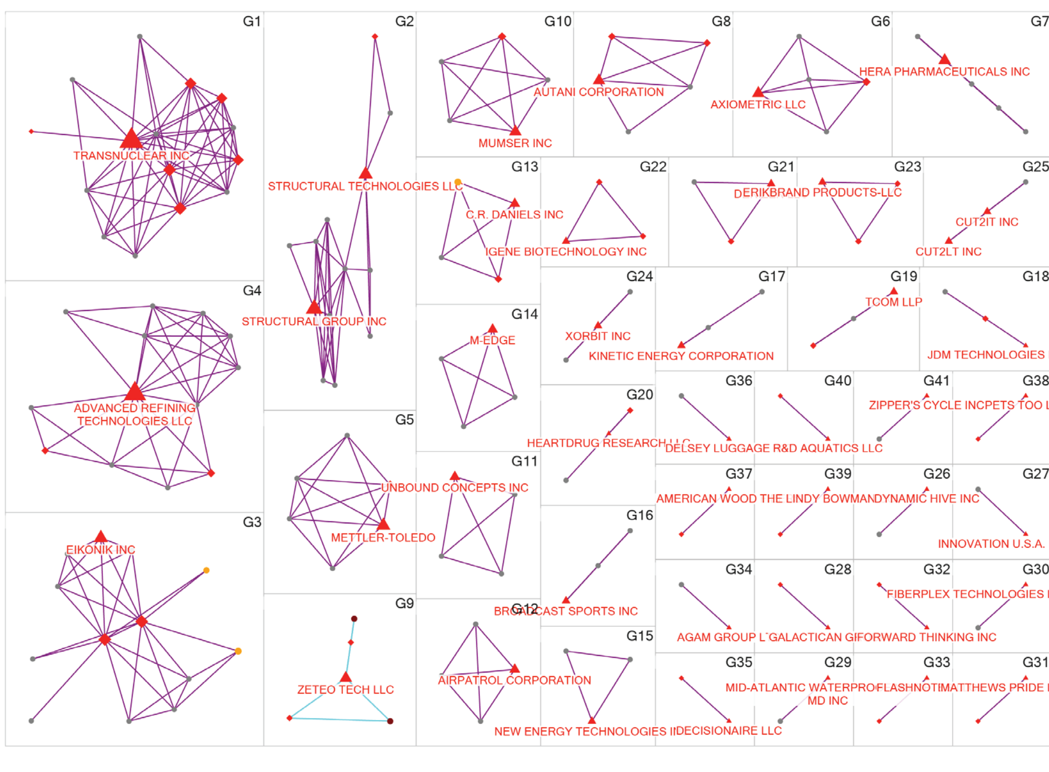
While additional research is needed to determine whether these inventions can be commercialized and whether the people involved have such intentions, image 8 nevertheless presents nearly 100 prospects for Howard County economic developers to engage as potential startups. Network image 9 identifies nearly 40 groups of people with connections to Howard County who have already started a firm in the County. While a few of these are more established many are either early growth or nascent startups that may need assistance in reaching the next growth stage. While the more advance firms in this group may be better addressed through BRE strategies, many may need the same type of startup assistance contemplated for image 8.

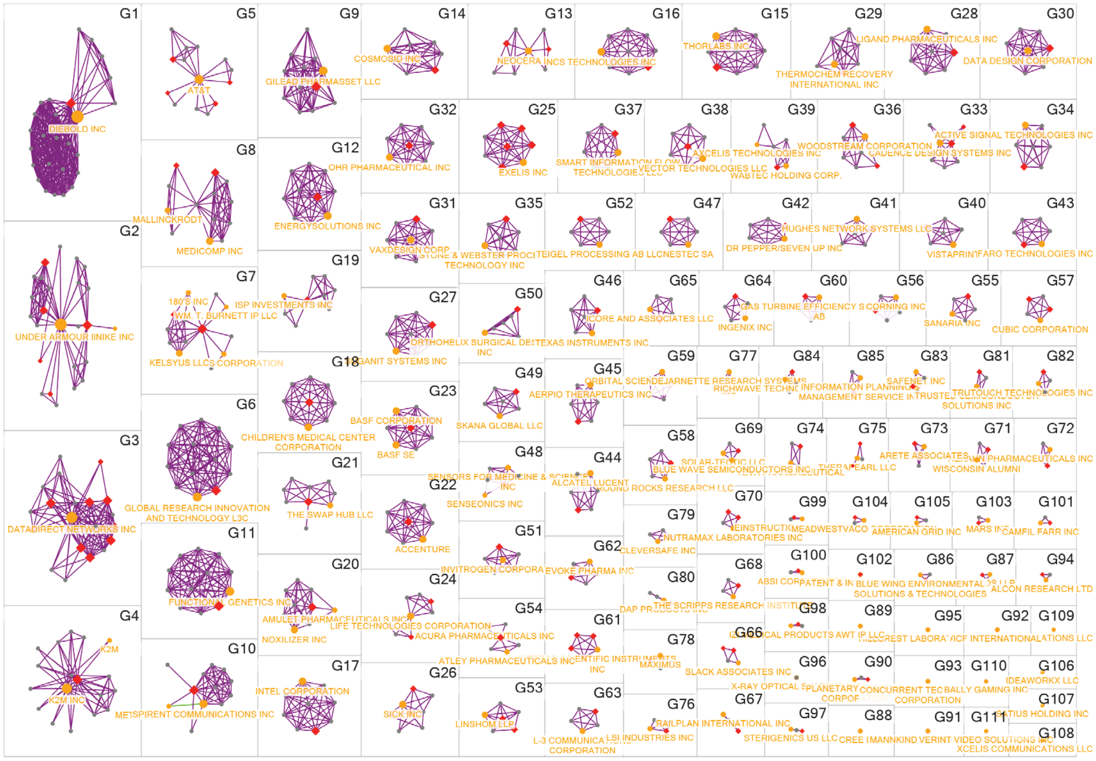
A different approach to business attraction In between the large firms and groups on the left side of the network graph (image 7) and the startups in the lower right corner of the graph



Top: Network Image 8

Bottom: Network Image 9





Created with NodeXL Pro (http://nodexl.codeplex.com) from the Social Media Research Foundation (http://www.smrfoundation.org)

Network image 10

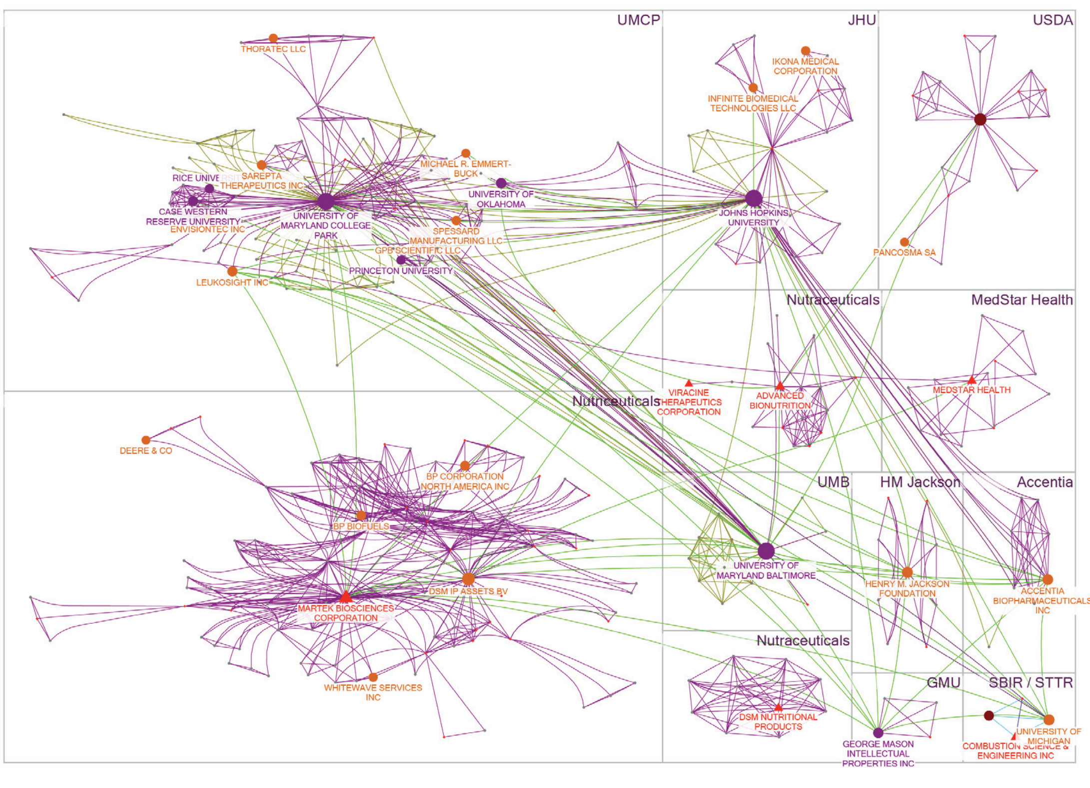
there are a large number of small and mid-size growth-oriented technology-driven firms (SMEs). Many of these SMEs are located outside of Howard County but have one or more connections to the County through the people involved in the company. Business attraction strategies have historically focused on attracting large firms with expensive incentive packages. In recent years support for such packages has waned with increasing scrutiny and shrinking budgets.

Innovation network analysis suggests a less costly alternative moneyball approach. Network image 10 identifies roughly 100 SMEs that are currently located outside of Howard County but which have one or more County connections. This presents HCEDA with a prospect list of people and firms to contact. But the strategy is more subtle than simply cold calling firms to see if they want to move. It is a strategy that focuses on the existing Howard County connections and how the firm might fit into one of the Countys technology clusters. It is a longer-term, lower-intensity approach that focuses on the firms next growth stage and seeks to establish relocation to Howard County at that stage as a viable and attractive option. While this approach may ultimately require the use of some incentives, each package is smaller and the total incentive investment is more diversified across firms, industries and geographic locations.

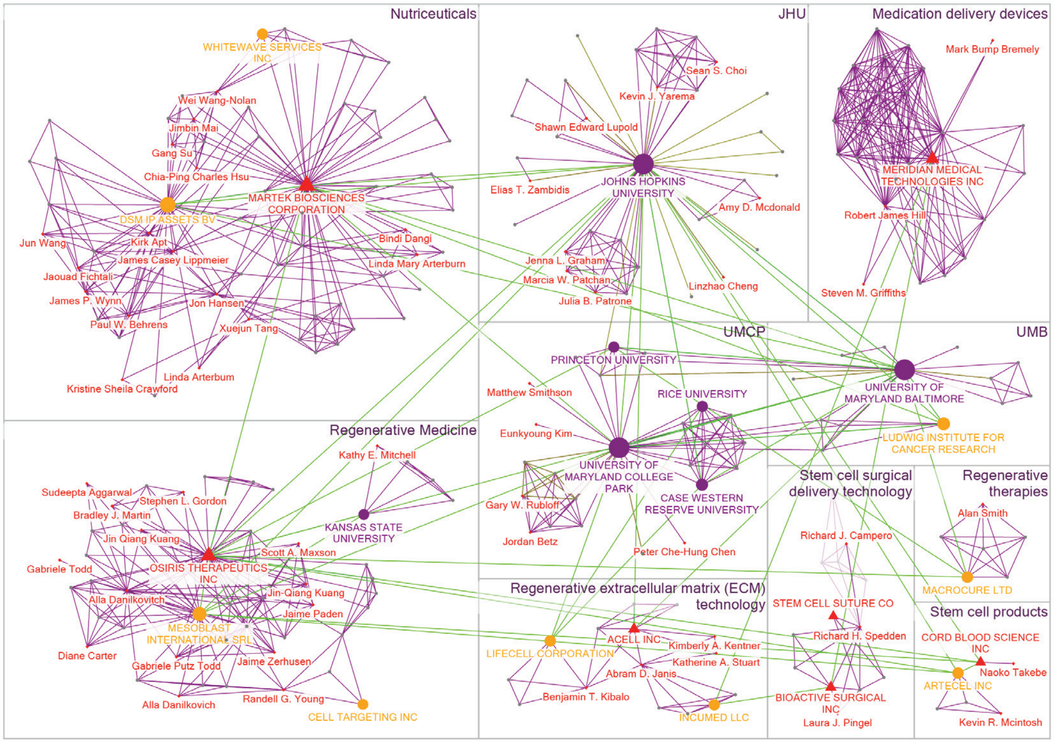
Technology Clusters

Consistent with industry cluster theory that defines clusters as groups of firms connected to each other through networks of collaboration and competition, the groups identified in our larger network images (image 2 and image 7, for example) may be connected to each other through technology-based (lime green) ties. Where we find these ties we are likely to find the types of relationships described in the industry cluster definition, or the potential for such relationships. Thus grouping network components together into technology clusters based on weak tie connections provides a partial look into those defining networks. The network-based technology clusters are a reflection of the innovations that people are actually working on rather than pre-defined industry groupings and industry cluster definitions. Because of this, the network-based technology clusters are more likely to reveal the direction that industry clusters are moving in terms of technology. They may reveal new emerging clusters years before they show up in the industry cluster analysis. These technology clusters may also reveal active and competitive sub-clusters within larger industry clusters that in the aggregate have lackluster location quotients. Our initial analysis revealed 5 technology clusters as described in the body of this report. These include the following:

Network images for each of these technology clusters except Research & Development are shown in network images 11, 12, 13 and 14.



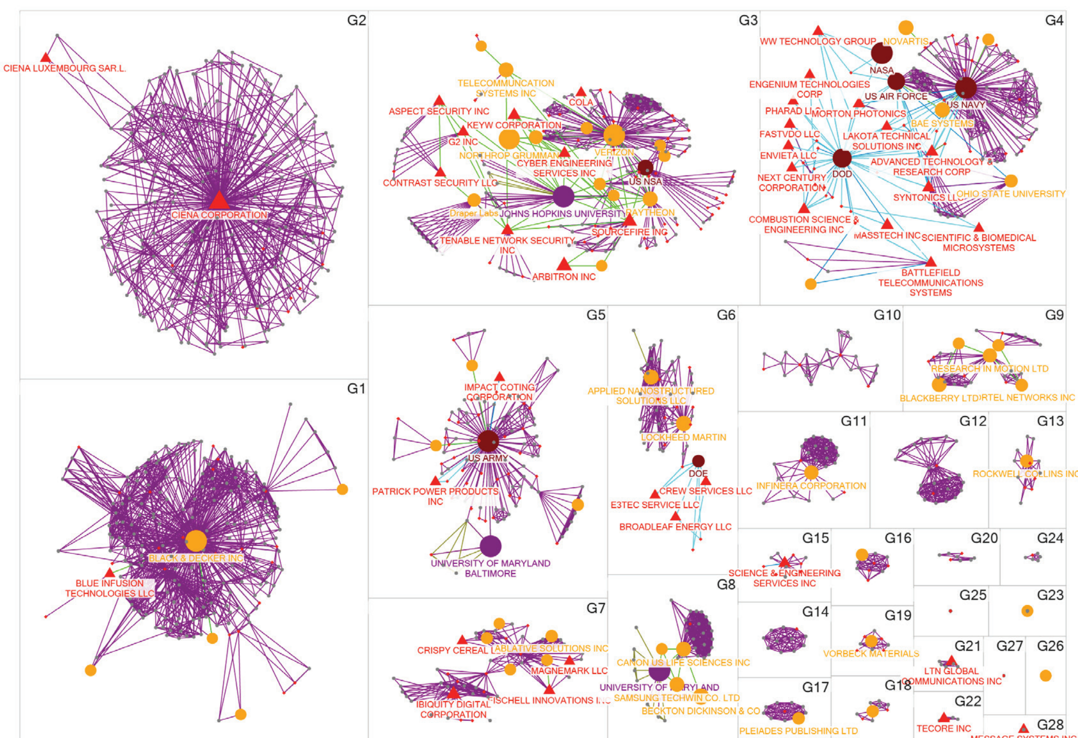
Network image 11



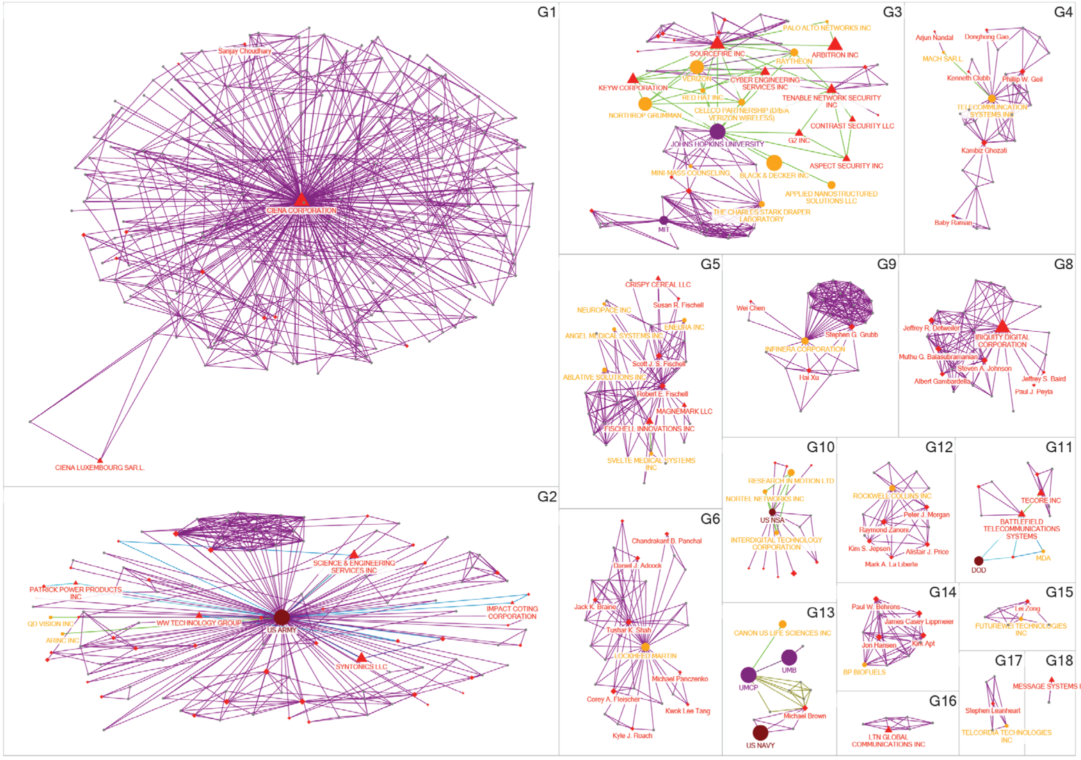
Created with NodeXL (http://nodexl.codeplex.com)

Top: Network Image 12

Bottom: Network Image 13

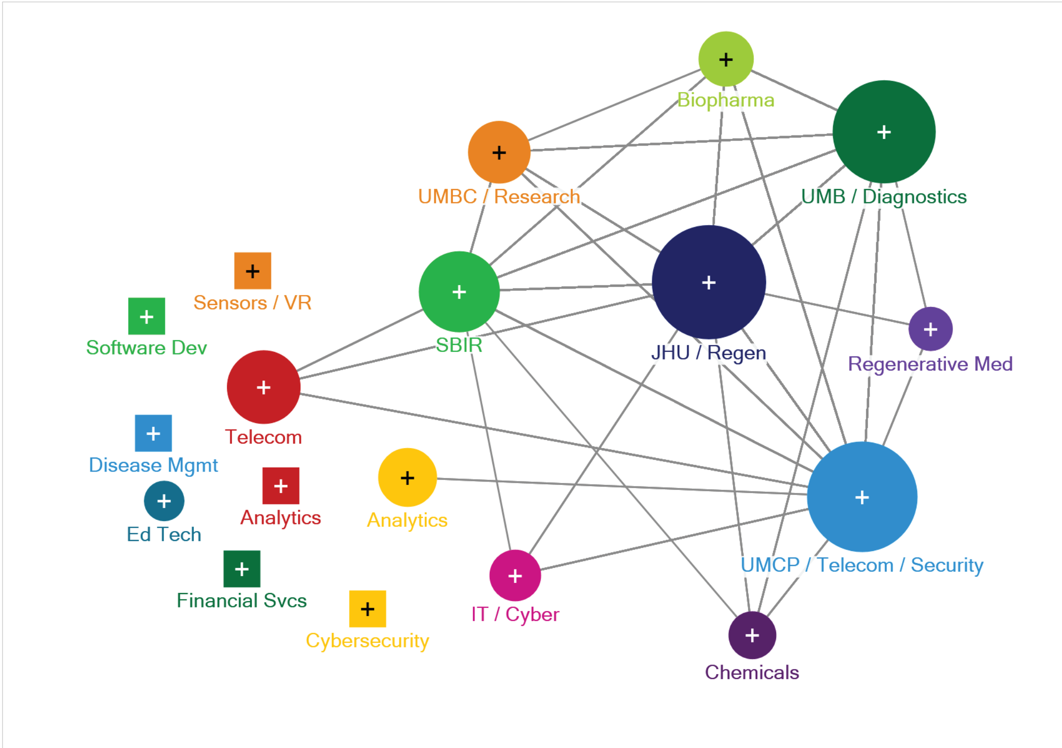


Created with NodeXL Pro (http://nodexl.codeplex.com) from the Social Media Research Foundation (http://www.smrfoundation.org)



Created with NodeXL Pro (http://nodexl.codeplex.com) from the Social Media Research Foundation (http://www.smrfoundation.org)

Network image 14



Network image 15

Towards the end of the semester a new method for identifying technology clusters was developed. Briefly, this method involves replacing individual vertices with their group assignments and generating a new model as a network of groups connected by weak ties. A clustering algorithm is run on this new network, identifying the groups that belong together based on weak ties. The resulting clusters showed strong similarity to our original five, but identified a total of 18 clusters as shown in network image 15. Each node in this network is a collapsed cluster representing multiple groups from the larger network (image 2) connected by weak (lime green) ties.

A Closer Look at the Regenerative Medicine Cluster

The regenerative medicine cluster is a good example of how innovation network analysis can augment more traditional methods of economic and cluster analysis. Industry cluster analysis does not pick up this cluster for a couple reasons.

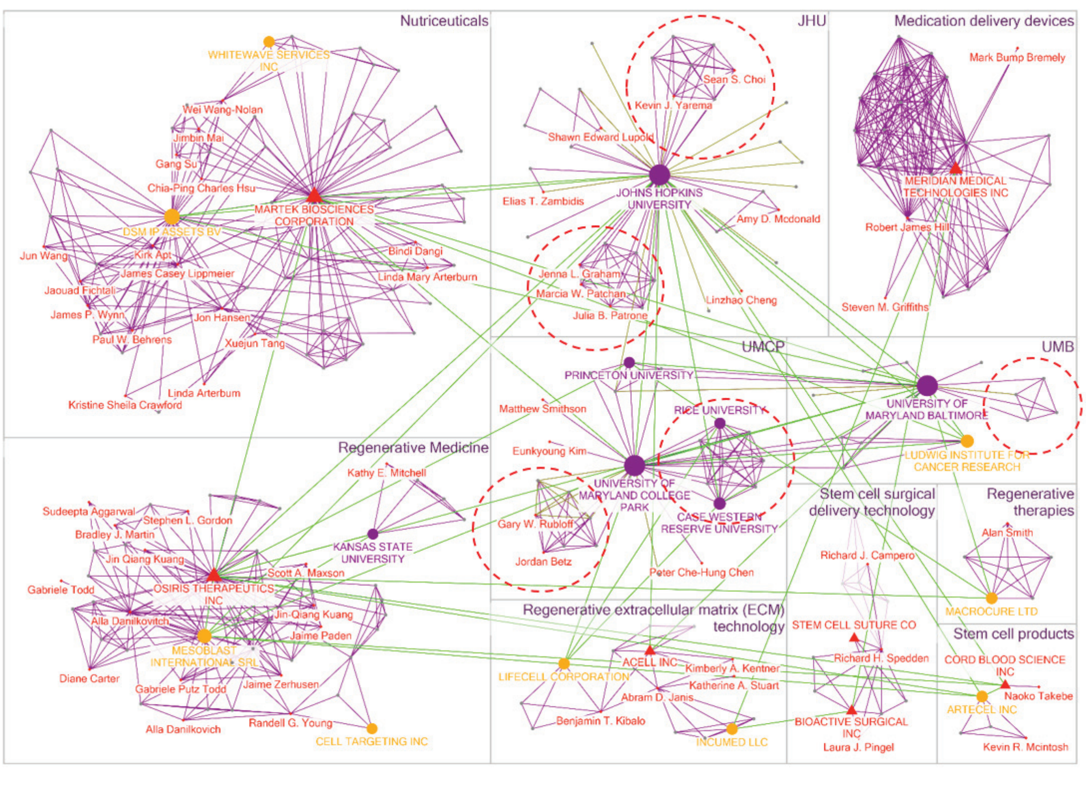
First, many of the firms are research based, filing under NAICS 541710 or 541720, both of which are suppressed at the county level. NAICS 5417 has an LQ of 9.60 but does not distinguish between bio-based research or any other type or research. Further, when this code is aggregated into industry cluster definition the concentration is diluted by other NAICS codes for which the County has little or no specialization.

Second, some of the firms in this cluster are relatively new and their impact does not yet appear in industry cluster data.

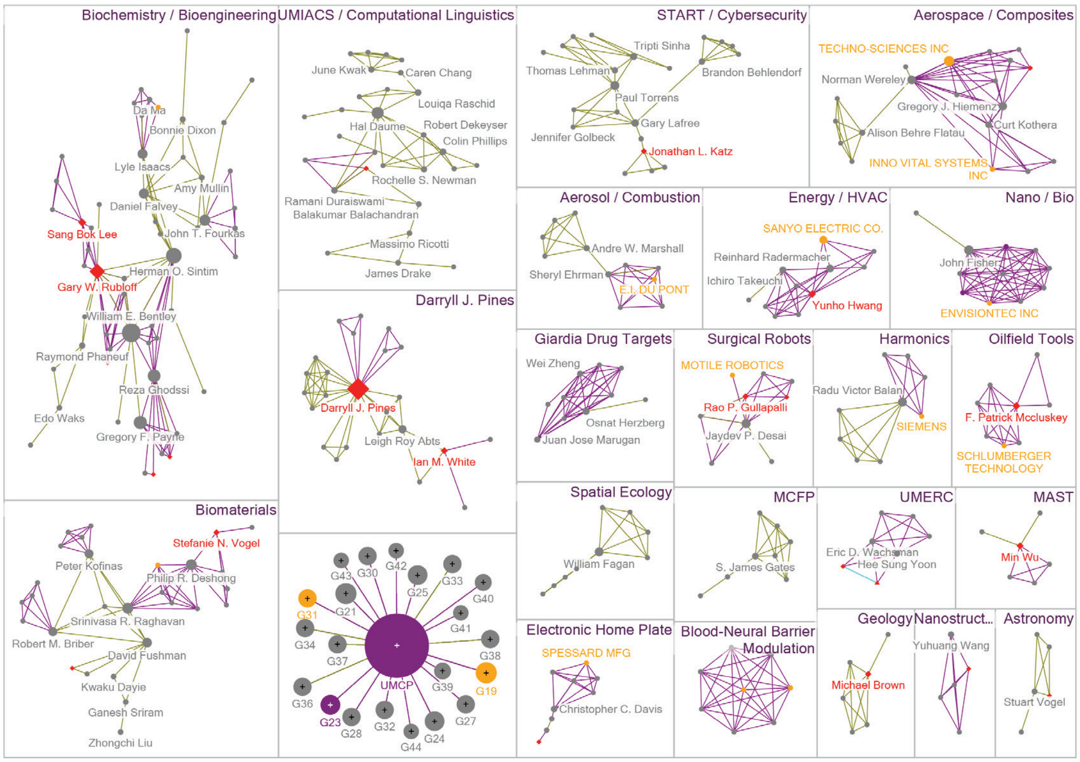
Third, the network analysis includes firms that may be located outside the county that nevertheless have a county connection. These are targets for potential business attraction.

Fourth, the network analysis identifies university involvement in the cluster and identifies specific labs / departments where tech transfer may be enhanced. So while network analysis does not replace cluster analysis, id provides useful augmentations and reveals very specific technology clusters that might otherwise be missed in a traditional analysis.

The body of this report provides an in-depth look at the regenerative medicine cluster. Here the focus is on interpreting the network graph (network image 16). This network image shares similar layout features with the other network graphs in that the largest component is located in the upper left corner while the smallest is located in the lower right. All of the discussions herein regarding how this layout provides an organizing structure for targeting economic development strategies also apply to this graph. Additionally, network image 16 shows the identification of several university labs or research partnerships (red circles) in the network structure. So for example the circled lab in the lower left corner of the UMCP cluster is part of a larger biochemistry/bioengineering research cluster at the University of Maryland College Park (network image 17) the largest, most active research cluster at UMCP, occupying the upper left corner. By using the net-



Network image 16



Created with NodeXL (http://nodexl.codeplex.com)

Network image 17

work graph to identify specific labs or research groups, HCEDA can engage with research universities more effectively to promote innovation-led economic development. Strategies may include the following:

1 Facilitating cluster-oriented sponsored research that can benefit multiple firms within the cluster.

2Targeting student startups and faculty spin-offs for inclusion and integration into the cluster. This could be coordinated with relevant accelerators / incubators in the region as well.

3Targeting the transfer or licensing of specific technologies (see network image 4).

4Working with specific departments / professors to identify workforce needs and track graduates into the County workforce.

5Work with specific departments to develop cluster-based internships that work with multiple firms.

Investigation of the companies included in the cluster reveals the presence of foreign-owned firms including DSM, for example. Having a detailed picture of the regenerative medicine cluster along with detailed and targeted cluster development strategies can help HCEDA work with Marylands Office of International Investment and Trade along with existing and potential international firms to attract growth and foreign direct investment (FDI) to the cluster and the County.

The regenerative medicine technology cluster includes a number of technology-based weak ties between firms in the cluster. Preliminary investigation suggests that these may indicate the potential for inter-firm collaboration around the development of certain technologies. HCEDA may have a role in bringing firms together and facilitating such discussions.

Finally, clusters generally and this cluster specifically are useful organizing structures for industry partnerships that can focus on developing shared solutions to shared problems, for example workforce development. HCEDA may have a role in convening and facilitating the start of an industry partnership under the state s EARN program. Working with the Network Models NodeXL network models for the overall network and each cluster are included in this package. To view / use these models you must download and install NodeXL. The free version is sufficient for viewing and modifying the networks without calculating metrics.

Company and Technology Profiles

Of the companies included in the NodeXL analysis, over 60 individual companies were identified that had significant and/or useful ties to Howard County. Qualifying ties included: a current or former operating location in Howard County; some record of association with an address in Howard County, e.g. via a grant or patent application; and/or a base of current operation in immediately adjacent areas of either Baltimore or Anne Arundel Counties. Individual profiles for each of these companies are included in the Appendix. These profiles include information on the size, location, activities, customers, innovation activity and key people involved with each of these companies.

In addition, these profiles include a color-coded bar indicating which of five technology clusters the company belongs to: Nutraceuticals, Defense/Intelligence/Security, Regenerative Medicine, Research and Development, and Telecommunications. These five clusters of possible interest were identified via alternate methods of sorting and arranging data in NodeXL. Some companies fit into multiple clusters. Where this was the case, a primary categorization is indicated on the company profile and any secondary categorization(s) are shown on the Cluster Categorization Chart in the Appendix.

In most cases, technology clusters of interest were represented by multiple companies of various sizes active in Howard County. The exception is the Nutraceuticals cluster, which only has one active company (DSM, formerly Martek Biosciences). In our view the presence of multiple individuals and institutions with ties to this successful enterprise, as well as the overall growth potential in this sector, warrant its inclusion in this report.

These profiles are intended to provide a quick orientation to innovative companies and technologies that may be worthy of additional follow-up by economic developers in the County.

Regenerative Medicine

While each of these clusters represents a possible anchor technology for an innovation-led economic economic strategy, Regenerative Medicine stands out as a unique opportunity due to the unique characteristics of the technology and the fact that it is at a nascent stage of growth in the county.

The National Institute of Health (NIH) defines Regenerative Medicine (2013) as the process of creating living, functional tissues to repair or replace tissue or organ function lost due to age, disease, damage, or congenital defects. (www.NIH.gov). The Regenerative Medicine Cluster has three sub groups: Stem Cell Surgical Delivery Technology, Medication Delivery Devices, and Regenerative Extracellular Matrix (ECM) Technology. Through the NodeXL analysis 25 companies were found in the Regenerative Medicine Technology Cluster. Of the 25 companies, six are located in Howard County.

Conclusion

So how do we spur innovation-led economic development in Howard County? We found that the multiple data analysis methods we applied illuminated a few key strategies for the County. Although traditional economic data analysis is limited in demonstrating innovation activity at the local level, it is still a good background and basis for comparison at the state level.

Our spatial analysis identified a cluster of innovation companies in the gateway center. We propose the county creates an innovation district in that area to help facilitate idea flow between people in these companies. This recommendation is long term as it will be challenging to implement a walkable innovation district in suburban Howard County. However, over time, the county can phase in public spaces, restaurants, coffee shops and walkable connectivity between the companies. To increase entrepreneurial activity, the county can direct resources and marketing efforts to the empty warehouses in our proposed district to help kick start companies by implementing makerspaces, accelerators, and incubators.

Finally, our network analysis resulted in five main technology clusters that are active in the County: Research and Development, Nutraceuticals, Regenerative Medicine, Defense, and Telecommunications. Based on these clusters (see figue X below), the next steps for Howard County Economic Development would be to identify and cultivate keystones and capital networks in each innovation cluster. The county can zero in on traditional economic development strategies in the following areas: workforce development, universities, business expansion and foreign direct investment opportunities, and business attraction opportunities.

Workforce Development Develop industry partnerships (EARN) around innovation clusters Work with universities and community colleges on talent pipeline Universities (JHU, UMCP, UMB, UMBC+) Follow-up leads for licensing or other engagements (represented by green ties in the network model) Identify key labs (dense subgroups) and evaluate for expansion/enhancement Identify opportunities for faculty spin outs identify/accelerate potential student startups that can be seeded in this cluster Build long-term sponsored research relationships with keystone companies Business Expansion & FDI Opportunities Focus BRE on growth stage and mature companies in innovation clusters develop keystones in the process engage MD DOC in developing FDI engage foreign-owned companies in innovation clusters to expand their presence in the cluster through FDI

Business Attraction Opportunities Focus on early stage companies with innovation cluster growth potential; companies are located outside of the county but have a HoCo connection Develop relationships and help them plan for move to HoCo for next growth stage Connections to capital

Bibliography

Archibugi, D. & Filippetti, A. (2013). Innovation and Economic Crisis: Lessons and Prospects from the Economic Downturn. Retrieved from https://books.google.com/books?id=X2WpAgAAQBAJ&dq=innovation+economic+downturn&lr=&source=gbs_navlinks_s

Atkinson, R. D., Ezell, S. J., & Stewart, L. A. (2012). The Global Innovation Policy Index. Information Technology and Innovation Foundation and the Kauffman Foundation.

Bender-deMoll, S., and McFarland, D. (2006). The Art and Science of Dynamic Network Visualization. Journal of Social Structure 7(1). Retrieved from http://www.cmu.edu/joss/content/articles/volume7/deMollMcFarland/

Boroush, M. (2010). NSF Releases New Statistics on Business Innovation. National Science Foundation Info Brief.

Brookings, Bruce Katz and Julia Wagner. The rise of innovation districts: A new geography of innovation in america. p. 1-14.

Cornell University, INSEAD, WIPO. (2015). Global Innovation Index Home. Retrieved from Global Innovation Index: https://www.globalinnovationindex.org/content/page/GII-Home

Chen and Yang (2010): Visualization of Social Networks. In: Borko Furht (Ed.), Handbook of Social Network Technologies and Applications (p. 585-610). Springer. Retrieved from http://link.springer.com.proxy-um.researchport.umd.edu/book/10.1007%2F978-1-4419-7142-5

Fears, R., Ferguson, M. W. J., Stewart, W. , and Poste, G. (1997). Life-Sciences R&D, National Prosperity, and Industrial Competitiveness. Science 2 May 1997: Vol. 276 no. 5313 pp. 759-760. DOI: 10.1126/science.276.5313.759

Fleischer, R., and Hirsch, C. (1998). Graph Drawing and Its Applications. In: Michael Kaufmann and Dorothea Wagner (Eds.), Drawing Graphs: Methods and Models. Springer. Retrieved from http://link.springer.com/book/10.1007%2F3-540-44969-8

Freeman, C., & Soete, L. "Developing science, technology and innovation indicators: What we can learn from the past." Research policy 38, no. 4 (2009): 583-589.

Fruchterman, T., and Reingold, E. (1991). Graph Drawing by Force-directed Placement. Software - Practice and Experience 21(11), 1129-1164. Retrieved from http://ftp.mathe2.uni-bayreuth.de/axel/papers/reingold:graph_drawing_by_force_directed_placement.pdf Hansen, D., Shneiderman, B. & Smith M.A. (2011). Analyzing Social Media Networks with NodeXL: Insights from a Connected World. MK Publications.

Jarmin, Ron S., Miranda, Javier. (2002). The Longitudinal Business Database. U.S. Census Bureau. Washington, D.C.

Investopedia. (n.d.). Solow Residual. Retrieved from Investopedia: http://www.investopedia.com/terms/s/solow-residual.asp

Landau, R., Rosenberg, N., & National Academy of Engineering. (1986). The Positive sum strategy: Harnessing technology for economic growth. Washington, D.C: National Academy Press.

Landesberger et al. (2011). Visual Analysis of Large Graphs: State-of-the-Art and Future Research Challenges. Computer Graphics Forum (Volume 30). Retrieved from http://web.a.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=fd476fa4-93e0-4ada-ba03-284637b96ac3%40sessionmgr4004&vid=2&hid=4104

Litan, R. E., Wyckoff, A. W., & Fealing, K. H. (2014). Capturing Change in Science, Technology,and Innovation: Improving Indicators to Inform Policy. Washington, D.C.: The National Academies Press.

New York City Economic Development Corporation. (2011). NYCEDC Innovation Index 2011. New York: New York City Economic Development Corporation.

Mackinlay, J. (1986). Automating the Design of Graphical Presentations of Relational Information. ACM Transactions on Graphics 5(2), 110-141. Retrieved from http://www.cs.rutgers.edu/~decarlo/readings/mackinlay-tog86.pdf

McKelvey, M. (2014) "Science, Technology, and Business Innovation." The Oxford handbook of innovation, p. 69-82.

National Science Foundation. National Center for Science and Engineering Statistics (NCSES): Science and Engineering Indicators 2014. Retrieved from http://www.nsf.gov/statistics/seind14/index.cfm/overview

Qian, H., & Haynes, K.E. (2013). Beyond Innovation: The Small Business Innovation Research Program as Entrepreneurship Policy. Springer Science+Business Media. New York.

Salter, Ammon, and Oliver Alexy (2014). "The Nature of Innovation." The Oxford handbook of innovation, p. 26-49.

Singer, P.L. (2014). Federally supported innovation: 22 Examples of Major Technology Advances that Stem from Federal Research Support. The Information Technology and Innovation Foundation. Retrieved from http://www2.itif.org/2014-federally-supported-innovations.pdf

Spruijt, J., Spanjaard, T., and Demouge, K. (2013). "The Golden Circle of Innovation: What Companies Can Learn from NGOs When It Comes to Innovation." Modern Marketing for Non-Profit Organizations: International Perspectives, S. Smyczek, ed., Katowice: University of Economics in Katowice Publishing House, Forthcoming.

Stephan, P. E. (2012). How economics shapes science. Cambridge, Mass.: Harvard University Press.

Strangler, D. & Bell-Masterson, J. (2015). Measuring an Entrepreneurial Ecosystem. Kauffman Foundation.

Small Business Administration. (2014). Small Business Innovation Research (SBIR) Program Policy Directive. Office of Investment and Innovation.

SSTI. Trends in Tech-based Economic Development:Local, State and Federal Action in 2013, p. 1-32.

The Impact of Firm's R&D Strategy on Profit and Productivity. The Royal Institute of technology Center of Excellence for Science and Innovation Studies (CESIS).

United States. H.R. American COMPETES Reauthorization Act of 2010. January 5, 2010. H.R. 5116, 2nd Session. Washington, GPO, 2010. Web. 16 October 2015.

Unwin, Theus and Hofmann (2006): Graphics of Large Datasets. Visualizing a Million. Springer. Retrieved from http://link.springer.com.proxy-um.researchport.umd.edu/book/10.1007%2F0-387-37977-0

U.S. Department of Health and Human Services. NIH Research Portfolio Online Reporting Tools. Retrieved from http://report.nih.gov/nihfactsheets/viewfactsheet.aspx?csid=62

U.S. Economic Development Administration. (n.d.). A Practitioner's Guide To Economic Development

Tools for Regional Competitiveness in a Knowledge-Based Economy. Retrieved from http://www.statsamerica.org/innovation/guide/practitioners_guide.pdf

U.S. Economic Development Administration. (n.d.). Innovation Index. Retrieved from StatsAmerica: http://www.statsamerica.org/innovationindex/Default.aspx

U.S. Economic Development Administration, Harvard Business School. (2014). Clusters 101. Retrieved from US Cluster Mapping http://www.clustermapping.us/content/clusters-101

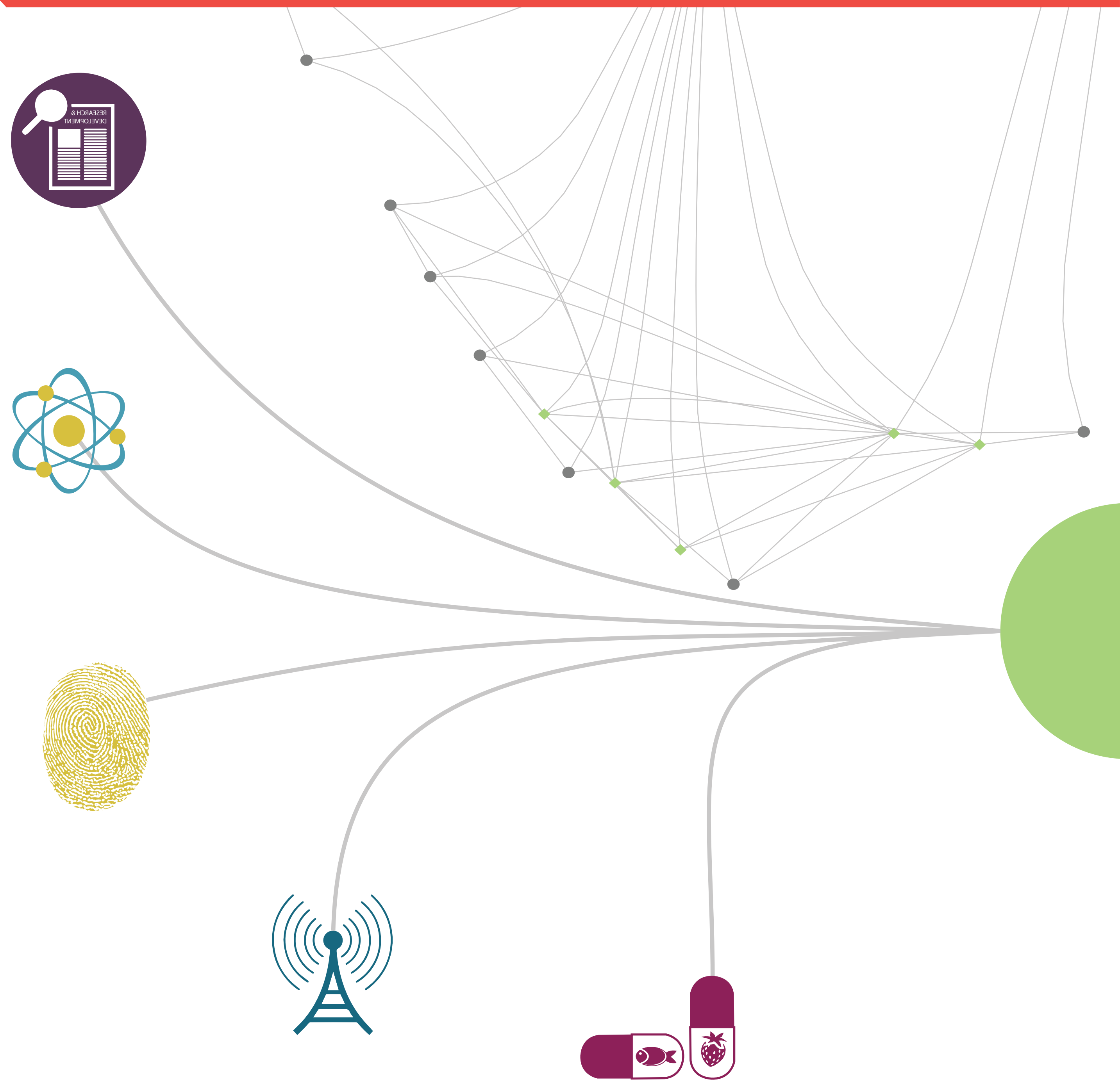
U.S. Patent and Trademark Office.

Wallsten, S.J. (2000). The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program. The Rand Journal of Economics.

Appendices

Appendices are available at http://www.terpconnect.umd.edu/~dempy/docs/studio2015/.

Including:
1. Network Models
2. GIS maps and data
3. Company Profiles


RESEARCH &
DEVELOPMENT