The Twin Cities Innovation Ecosystem: A Study of Stakeholder Perspectives

by

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1.0 Introduction

City leaders across the United States and around the world are promoting technological innovation as a way to grow their regional economies. The value of investing in technological innovation can be traced back to Joseph Schumpeter's work in economics during the early 19th century (Drejer, 2004). Schumpeter suggested that technological innovation yields positive economic gains for a given region, despite the possibility that it may harm other regions or industrial sectors. Robert Solow's 1956 paper, *A Contribution to the Theory of Economic Growth*, which contributed to a Nobel Prize in Economics, built upon Schumpeter's theory and offered evidence that technological innovation is a key factor for economic growth. More recently, Michael Porter's (1990) work, *The Competitive Advantage of Nations,* showed that investments in science and technology can provide numerous benefits including prestige (e.g. space race), military prowess (e.g. nuclear weapons), and economic power (e.g. electronics).

In the past two decades, Ann Saxien (1996) and other scholars have turned their attention to *regional innovation systems* by showcasing the economic growth in Boston and Silicon Valley associated with longstanding investments in science and technology. In another study, Feldman and Florida (1994) isolated four variables within urban regions that contribute to economic growth, including industrial R&D, university R&D, firms in related industries, and business services that foster innovation. In response, many cities offered different funding mechanisms, tax incentives, and funded private-public partnerships in attempts to jumpstart technological development. Around the same time, Leydesdorff and Etzkowitz (1998) posited that dynamic disequilibrium among the "triple helix" of industry, academia, and government can foster innovation by maintaining competition while avoiding collusion and stagnation.

Dan Stokols and colleagues (2019) at the University of California built upon the "triple helix" theory and conceptualized how individuals within organizations connect to funding agencies, private sector partners, and non-governmental organizations. They propose that individuals working within larger teams are positioned within a node that is connected to the wider ecosystem. The team is surrounded by a working environment that enables (or constrains) their performance based upon organizational and physical features, for example the bureaucratic approval processes or the spatial configuration of the work environment. Beyond the team's immediate work environment is the institutional context that set the rules within an academic, government or private organization. The institutional context can be even more complex if the team works within a university-industry partnership, as one example. Beyond that institutional context is the broader environment of supporting organizations with whom different individuals within the team need to interact, and those interactions are mediated by their own institutional context.

These studies, among others, often gather evidence and assess the success of cities and states that have enacted policies that directly (and indirectly) support the organizations pursuing innovation, as well as the service providers. Cities have supported both public and private organizations by transferring city land to organizations seeking to build new infrastructure or offering zoning easements to science and technology-based organizations. Other cities have tried to generate positive interactions among academic, government, and private industry (large and small) to nurture a regional innovation hub, which can result in the formation of new firms (Avnimlech & Feldman, 2010). Such strategies can be observed in the agendas set out at the US Conference of Mayors (2018) and other venues.

The primary assumption is that any city can become a prosperous innovation hub and sustain economic growth. And success is often measured in terms of dollars spent on research and development, expenditures by firms in related industries, degrees awarded, and expenditures for business services that

support innovation, e.g. patent attorneys. However, some scholars are starting to question if measures of economic growth alone are adequate to assess the implications of regional innovation policies.

Many scholars, including Bozeman (2002) and more recently Uyarra and colleagues (2019), argue that broader goals and public values can be supported through investments in technological innovation. The rationale is that the process of innovation should not only generate wealth, but also should be broadly inclusive of diverse persons, consider the future implications of technology, and afford opportunities for individuals and organizations to change their course of action. Those public values might well complement the goals of economic growth and offer a more comprehensive set of criteria to assess the outcomes of the innovation process.

This research explores the following question: Who is doing what to pursue innovation, and why? This question affords an opportunity to understand *who* the organizations are that are working on innovation and *what* actions and activities they are taking in that pursuit. The *why* pertains to the motivations and goals that inspire those organizations to take action. To address these questions, this project will rely upon interviews with selected participants from metropolitan Minneapolis and St. Paul (or Twin Cities), see the detailed methods in Section 4.0 below. The participants were selected from organizations that regulate, fund, advocate, research, and otherwise work with technological innovation. The following section details the scope and boundaries used to frame this research.

2.0 Scope and Boundaries

This research project builds upon, but does not report on traditional, economic measures of innovation within an urban region. Many studies issued by government agencies, industry associations, academic offices and consulting firms often gather a set of indicators based upon economic measures of growth. This study does not include those indicators, including the following:

- Firm formation (new entrants)
- Valuation of technology firms (market size)
- Mergers and acquisitions reported (consolidation)
- Research expenditures in private firms and academia (expenditures)
- Licensing agreements (technology transfer)
- Patenting and publication activity (network relations)

Many of these indicators support the Case Context section and offer a backdrop for this project, yet they are not the focus.

3.0 Case Context

The Twin Cities, which references Saint Paul and Minneapolis, is an expansive metropolitan region defined by the US Census as the "Minneapolis–St. Paul–Bloomington MN-WI Metropolitan Statistical Area" (U.S. Census, 2010). Historically, economic growth in the Twin Cities was connected to the storage and processing of grain and other agricultural commodities. The headquarters of General Mills, Pillsbury, and other food processors brought about the Minnesota Grain Exchange (Twin Cities Pioneer Press, 2018). St. Paul, positioned on the Mississippi River, is the northern most navigable port to New Orleans and out to the Gulf of Mexico and offers extensive avenues via rail to shipping ports in the Great Lakes, which is known as the Great Loop (Gardner, 2017). Today, the Twin Cities Agricultural products, services, and

ancillary economic activity are still important to the region's economy, but technology-based firms expanded in the post-World War II era.

In the early 1980s, the Office of Naval Research sponsored a novel research project led by Andrew Van de Ven and colleagues (1986) called *The Minnesota Innovation Research Program*. That study investigated thirteen subject areas from microelectronics and medical products to multi-hospital systems and programs to commercialize outer space, all of which were underway in the state. Van de Ven and colleagues (1989) issued an edited volume that shared the lessons learned from that longitudinal study, which was later republished in paperback form by Oxford Press. The section of this book dedicated to technological innovation featured chapters which are titled: *Managing complex innovations: The case of defense contracting; Assessing the emergence of new technologies: The case of compound semiconductors; The management of research and development of a biological innovation;* and *Technological innovation and industry emergence: The case of cochlear implants*. Those cases offered analysis of the people, ideas, transactions, context, and outcomes from those different sectors, which Van de Ven and colleagues later summarized in *The Innovation Journey* (1999). Of course, others have written compelling narratives that retrace innovations nurtured within firms in the region. For example, the development of 3M's Post-It® products is recounted in a famous case study of innovation (McNerney, 2002), as is Earle Bakken's work in his garage (Kenny, 2008). There are plenty of stories of invention and commercial success attributed to firms in the region.

Yet what those stories focus on are individual firms, the people within those firms, and their relationships to discrete organizations outside the firm. The urban setting where those events took place serves only as the backdrop. In the wake of the "Minnesota Studies" led by Van de Ven, graduate students investigated factors in the region beyond an individual firm or sector (Ball et al., 2012). That report returned to many findings from Florida and Feldman (1994) and offered evidence of each. While significant scholarship has been dedicated to the urban innovation hubs of Boston, Silicon Valley, the Research Triangle, Austin, and San Diego, there is little published about the Twin Cities as an innovation ecosystem, c.f. Avnimlech & Feldman (2010) or Saxien (1996). This research project aims to explore the people, organizations and places that constitute the city. Rather than focus on the "hero's journey" of innovation, this study will look at the innovation ecosystem more holistically.

One major research effort that is funded and pursued nationally is in nanotechology, which will serve as part of the "research boundaries" for this case study. Since the late 1999's when former President Clinton launched the National Nanotechnology Initiative, there has been significant funding, built infrastructure and training invested into this cross-cutting research field. Nanotechnology research and development is present in hundreds of firms, university research laboratories and in thousands of products sold today. This boundary gives attention to "high tech" research, development and innovation and secondarily emphasizes products that are designed and built. Thus, it excludes marketing, software development and other innovative fields.

At the University of Minnesota (UMN) there is a Materials Research Science and Engineering Center (MRSEC), which focuses on electrostatic controls, nanocrystal growth, and multifunctional materials at the nanoscale (UMN, 2018). That research center is funded by the National Science Foundation (NSF). Another investment by the NSF resulted in the creation of the I-PRIME program, which is a university-industry partnership that contributes to research into foundation engineering and sciences of polymers at the nanoscale. In medical devices and equipment, UMN hosts 7-10 fellows in the Earl E. Bakken Medical Devices Center (2019), where they work to create innovative ideas at the intersection of medicine, engineering, and business. Many of the products created rely upon nano-enabled polymers, structures

and electronics. The Institute for Engineering and Medicine also facilitates interactions between industry, academics, and healthcare practitioners by creating opportunities for shared learning and directed research into specific topics (IEM, 2019).

The UMN is home of the Midwest Nanotechnology Infrastructure Corridor (MINIC). Both the MINIC and MRSEC research centers are funded by the NSF. The University of Minnesota reported $940 million in research expenditures in 2016 and $948 million in 2017, with $33-36 million in research funding received from industry (AUTM, 2016; AUTM, 2017). That effort yields about 400 invention disclosures annually and resulted in 200 and 235 patent applications in 2016 and 2017, respectively. The university executed 73 exclusive licenses and filed 257 disclosures in 2016, and executed 51 exclusive licenses, making 283 disclosures a year later. That yielded $45 million and $22 million in gross income for each of those two years, respectively (AUTM, 2016; AUTM 2017). Other universities and colleges in the metropolitan region are active in nanotechnology research and some scholars from those schools have earned federal grants, filed patents and issued hundreds of papers.

The University Enterprise Laboratories, located between the Minneapolis and St. Paul campuses of the UMN, is one of the few facilities that offers wet labs and small cleanroom operations for small firms (UEL, 2019). The tenants include faculty-led research startups, but the facility is primarily rented by entrepreneurs without ties to the university. Faculty research that may have commercial value is supported by the I-Corp Program that is integrated into the Discovery Launchpad Program and the Venture Center (2019). The Discovery Launchpad boasts that $397 million in capital has been attracted in the past decade by the 119 start-ups and 18 start-ups formed in 2017 alone. There is a growing number of incubators and accelerator programs that support entrepreneurs in the Twin Cities with over a dozen programs and facilities dedicated to the task (Beier, 2018). Organizations including the Twin Cities Innovation Alliance (2019) are working to bring issues of inclusion and diversity to the forefront, alongside the narratives of economic growth and financial investments.

Recently, the Twin Cities was ranked #21 for "Start-up Friendly" cities in the United States (Derballa, 2019), while the metropolitan area was ranked #7 in overall patenting activity between 2000-2011 (Belanger, 2014). Organizations like the Medical Alley Association documented over $1 billion in capital in 2019 raised by start-ups in the region (Niepow, 2020), which reinforces the strength in that sector. The metropolitan region raised $491 million in 2016 from venture capital, which ranked #18 among regions in the nation that year (Florida, 2017). The Minnesota High Technology Association reported that an estimated 50% of capital raised is in the medical device and equipment sector. The Twin Cities region's healthcare-industry collaborations between UMN Hospital, the Mayo Clinic, and local medical device firms helps draw talent from the upper-Midwest and around the world to work in medical devices and healthcare, more generally (Greater MSP, 2016). For those reasons, and many others, the area attracts contract biomedical research facilities, which include small to medium-sized companies in the region.

Specific to this study's focus on nanotechnology, a systematic search of nanotechnology patents revealed 5,616 patents were issued in Minnesota between 2013-2016 with 2,554 issued to organizations within the metropolitan region. Similarly, the Twin Cities were the home to authors of over 26,557 peer-reviewed research papers on nanotechnology in 2017, alone. Youtie and Shapira (2008) classified the Twin Cities as "diversified" in nanotechnology based on relatively higher rates of private patenting as compared to other cities. The region is home to the corporate headquarters of 3M, Honeywell, Target, as well as the region for major research and manufacturing for Medtronic Inc. and Abbott (formerly St. Jude Medical). Those private firms contribute to the region's relatively high ratio of patents per 100,000 workers (USPTO, 2017). Medical devices and equipment are the state's top export with a value of $4.5

billion per year (MN DEED, 2019a) and manufacturing remains strong with over 8,500 manufacturers in the state that employ over 320,000 people and produce around $50 billion in gross domestic product, annually (MN DEED, 2019b).

4.0 Research Design and Methods

The research design is informed by the overarching academic theory of innovation ecosystems, which suggests that different organizations and individuals have differentiated and specialized roles that affect the processes and outcomes of technological innovation. Innovation here is defined as the processes of ideation, creation, and broader uptake of novel products or manufacturing processes (Foley and Wiek, 2013). This study focuses on nanotechnology innovation, including the manipulation and manufacturing of materials that are below 100 nanometers in size or exhibit novel characteristics at the nanoscale (Roco, Mirkin & Hersam, 2011). The contemporary practices of innovation in the Twin Cities are investigated by asking the question: Who is doing what with nanotechnology and why? That question draws upon notions of *real-time technology assessment* (Guston and Sarewitz, 2002) and *responsible innovation* (Owen et al., 2012).

4.1 Study Population

To catalog the organizations in the Twin Cities, initially the innovation ecosystem was divided into nine sectors based upon the organizations' functions, see Table 1, below. Each sector was then populated with a list of organizations from a variety of sources including publications, patents, grants, websites, and public directories. Organizations were identified if they had issued a patent and/or authored more than five academic journal articles that were pertinent to nanotechnology and based in the metropolitan area of the Twin Cities. Persons awarded grants related to nanotechnology were identified from public funding databases including the Small Business Innovation Research awards, National Science Foundation and National Institutes of Health. Additional parties were identified through web searches, written documents, and web publications issued by governments, consulting firms, industry associations, and academic researchers. Industrial divisions that operate independently at large companies, e.g. Boston Scientific and Honeywell, were treated as separate entities. In a similar fashion, major laboratories and research groups within universities were listed separately. A total of 558 organizations were compiled with at least eight in each sector, see Table 1.

Table 1. Twin Cities Innovation Ecosystem Population and Sampling. The first column indicates the sectors that were identified. The next columns are labelled as the number of organizations identified, selected (randomly), and directly recruited, as well as the count of interviews completed.

Sector	Identified	Selected	Recruited	Completed
Media	17	5	4	2
Insurers	9	3	2	1
Academic Units	180	60	55	13
Public Funding	21	7	4	3
Private Investors	94	31	12	8
Non-Profits	10	4	3	2
Regulators	8	3	3	2
Consultants, Lawyers & Business Support	61	20	14	6
Industry	158	53	5	12

4.2 Data Collection

Just under 190 organizations (over one-third of all organizations) were randomly selected from the full list. A leader or key figure from each organization was then identified based upon public information. Those individuals were contacted with a request for an interview via phone, email, and/or in-person. Recruitment stopped when 49 interviews were completed across the 9 sectors in a manner that offered balance and representation among the nine sectors. The interviews were all conducted in-person at the individual's office or at a mutually agreed upon location between April 1st and May 30th of 2019. The interviews lasted from 45 to 75 minutes and followed a protocol approved by the Institutional Review Board for Social and Behavioral Sciences at the University of Virginia. Participants were first asked questions that validated the researcher's knowledge of their background. Then they were invited to share a narrative about nanotechnology-based innovation in the Twin Cities and the researcher asked follow-up questions to guide the narrative in a semi-structured manner. The second phase of the interview involved the researcher re-stating the key organizations and individuals identified in the narrative and asking three follow-up questions. Those questions were:

i) What are the responsibilities of that organization/individual for innovation in the Twin Cities?

ii) How well are they fulfilling their responsibilities on a scale of 1 (low) to 5 (high)?

iii) What barriers or constraints are affecting the fulfillment of responsibilities by this organization (internally or externally)?

4.3 Data Analysis

The data that largely informs this report was derived from the second phase of the interviews, as the narratives will take additional time to curate and analyze for key themes. A data file was compiled including an aggregated list of responsibilities, fulfillment scores, and constraints for each organization mentioned by each participant. The initial analysis identified the most frequently mentioned organizations. The responsibilities and constraints for those organizations were clustered thematically and are reported. The responsibilities for each of the top 10 parties were aggregated and condensed by general theme, after which they were ranked in terms of how frequently they were mentioned across all interviews. The same process was repeated with the constraints identified for each organization. Finally, the average fulfillment score assigned by participants was calculated for each organization, and z-scores were calculated to offer a relative ranking of organizations to the mean-score. Using the frequency of mentions between organizations within each sector, an agent network map was built with connections represented by lines proportional to the average number of times that an organization was mentioned per interview.

Recurring themes include the most common constraints and success factors within the Twin Cities region and quotes from the interviews were selected to help give insight into the specifics of that theme. A draft of the analysis was presented to interview participants during two workshops in early November, 2019 in the Twin Cities. The 17 workshop participants offered feedback and the dialogue generated during that workshop further supported the interpretation of the findings by validating, reforming and/or offering alternative explanations.

5.0 Findings

This section offers detailed findings from the interviews conducted in the Twin Cities in the spring of 2019 and is organized in a manner to offer discrete pieces of evidence. The first portion reports on the most prevalent industrial sectors engaged in nanotechnology innovation and the patterns of activities within those sectors. That analysis is followed by a map of the ~550 identified organizations within the metropolitan region, which suggests the geographic areas where innovation activities take place. Then, a network analysis of the innovation ecosystem is displayed (aggregated and anonymized), which identifies the organizations that are most frequently mentioned and the extent to which those organizations are connected to others. Next, the most frequently mentioned organizations (aggregated and anonymized) are reported, which sets up a detailed review of the key responsibilities, fulfillment level of those responsibilities, and constraints. The evidentiary sources for these findings include the interview data and statements and reflections made by the workshop participants.

5.1 Innovation Pathways by Sector

The innovation ecosystem that supports the creation and production of nanotechnology-enabled products and services is clearly present in five distinct economic sectors including Medical and Biomedical Technologies, Information and Communication Technology (ICT) / Internet of Things (IoT), Energy and Environmental Technologies, Petrochemical Technologies, and Agriculture (see Table 2). The most prominent of these sectors is MedTech & BioTech with nineteen (19) participants offering narratives about innovation in that sector. This finding is not surprising given that several legacy medical device firms were founded or have major operations in the Twin Cities. Those legacy firms have given rise to the formation of teams that spin-off and/or spin-out from these large firms, as well as research endeavors that seek acquisition by larger corporations in the region. The research enterprise and strategic partnerships between private industry and large teaching and research hospitals support the foundations for innovation in Medical and Biomedical technologies. To one workshop participant it became clear that it was important to, "keep big fish here and foster relationships with entrepreneurs."

Fifteen (15) participants offered narratives about Information and Communication Technology (ICT) / Internet of Things (IoT) that address the creation of sensors and manufacturing processes related to electronics and semiconductors. Materials research within universities and firms is related to semi-conductors designed for ICT and IoT devices. These narratives originated with prior experience and user engagement and the goal was often entering into strategic partnerships with clients. While eight participants offered stories about research and innovation related to renewable energy, environmental quality, and environmental health, those narratives ended with continued work on materials and process improvements, testing and validating solutions, and only culminated with a government buyer. As compared to innovation in MedTech/BioTech and electronics in ICT/IoT, efforts in renewable energy and environmental quality technologies were not achieving market success.

The narratives related to petrochemical innovations built upon strong industry-university partnerships that were long-standing and benefitted both parties. The narratives originated with prior expertise and prior relationships, and sparked research in university laboratories. The innovation pathway converged on testing and scaling manufacturing capacity and transferring the intellectual property to private firms. There are even structured forums for industry leaders to offer feedback and guide the next phases of the research efforts by university faculty. This cyclical process between project formation and feedback takes about 1 year or two, with annual events punctuating the cycle.

One economic sector that is very important to the region is agriculture, yet only two narratives about high-tech innovations in the agricultural sector were captured. The two narratives on agricultural innovations enabled by nanotechnology were both well on their way toward global distribution. The

research efforts by those firms were adopted and integrated into the global agricultural supply chain, which has deep roots in the Twin Cities area. As one workshop participant commented, "I was surprised there wasn't more agriculture." Yet, discussion centered around the scope and boundaries of this project and how it excluded significant research into crop science.

There are distinct patterns of innovation among these sectors that can be attributed to differences in regulatory structures, commercialization strategies, and regional assets. Innovation within two sectors that are core to the local economy, MedTech/BioTech and ICT/IoT, originate with existing employees in the Twin Cities region who form new firms or new research groups within an existing firm. Secondarily, one of the core activities is engaging with users. There are long established and trusted relationships between university research centers and hospitals with private firms. Those relationships facilitate user engagement and structured observations of medical procedures and operations. Those insights, along with follow up conversations, often support "User-Driven" innovation. When discussing this, one workshop participant spoke up quickly, saying "It isn't that medical device [firms] don't care about the science, they do, but they are focused on learning from the doctors, attendants and patients." Another person added, "The tech has to work, ok. But does anyone need it? Is it worth it?" A discussion about the history and expertise in medical device technology in the Twin Cities confirmed the importance of the trust and longstanding relationships that facilitate these activities.

The secondary pattern of innovation in the ICT & IoT sector was "closed collaboration" in which two partner organizations entered into an exclusive rights agreement to research and develop new technologies. That pattern fits with cultural norms around trust building and long-term relationships. As one workshop participant reflected, "Isn't that how everything gets done here? Trust." As one participant stated, "Closed collaboration makes sense – for proximity, value and clusters of businesses geographically." Another said, "Look, we let them take the risk and then when it is ready, we buy it. We buy the staff or just the tech." This pattern, while operationally different from the industry-university relationships in petrochemicals, was similar in the ways that legal agreements formalized longstanding relationships between organizations. And for the larger firms in the region, the partnerships extend to companies with operations around the world, yet are longstanding and built upon trust that is solidified with contractual agreements.

The other pattern that was observed was the "Science Push" model of innovation that often arises out of university-led research initiatives. This pattern involves the discovery of a novel material properties or techniques, and the university researcher then discloses that invention. This pattern of "Science Push" was prominent in the "green tech" (e.g. renewable energy), which was aggregated with "clean tech" meaning technologies that address environmental health. Those narratives exclusively originated with university-led research and then followed the researcher's efforts to demonstrate the value of that knowledge in commercial settings. As one participant reflected, "Some collaborators may actually connect to [firm], who is pushing nanotech ideas." Another workshop participant stated, "I would have expected the EEQH (Energy, Environmental Quality and Health) to have more overlap with MedTech in terms of success." Another participant said, "There are no incentives to adopt the Green or Clean tech. It needs to out compete the market because the incentives are not stable." Another workshop participant offered this question about the lack of success in this sector, "Are there not enough financial incentives for industry to pick up innovators? If there's no incentive to adopt it, it might not go anyway." While little success has been realized in the renewable energy sector in the Twin Cities, there are firms such as 75F (not interviewed for this study), which are having success attracting funding and working to integrate IoT with energy efficiency programs.

Table 2. Innovation Pathways by Sector. The first column indicates the sectors that were present within the interviews. The next six columns are labelled as phases of innovation and were used to demarcate discrete phases of the participants' narratives about the innovation pathway. Starting with the second row, the sector, such as MedTech & BioTech (Medical Devices Technologies and Biosciences Technology) is followed by the number of participants' that spoke about innovation in that sector; for example, (n=19) means that nineteen participants shared narratives about innovation in that sector. Reading across the row, the core activities are named, for example, "Prior Expertise" is followed by (7), which indicates that seven people started the narrative with that action or activity at the core.

Sector	Phase I	Phase II	Phase III	Phase IV	Phase V	Phase VI
MedTech & BioTech (n=19)	Prior Expertise (7) Firm / Team Formation (7) Research (4) Concept Dev / Prototyping (2)	Concept Dev / Prototyping (6) Engage Users / Identify Need (6) Firm / Team Formation (3) Research (5)	Concept Dev / Prototyping (9) Transfer IP (5) Engage Users / Identify Need (4)	FDA Clinical Trials Invasive (9) FDA Clinical Trials Non-Invasive (8) Non-FDA Pathway (2)	Firm / IP Acquisition (10) Market & MFG within Firm (4) Distribution via 3rd Party (2)	Global Distribution (6)
ICT & IoT e.g. Sensors & Chips (n=15)	Prior Expertise (7) Engage Users / Identify Need (6) Research (2)	Firm / Team Formation (10) Concept Dev / Prototyping (4)	Test and Validate Solution (9) Make Process Improvement (4)	Expand Relationship (6) Attract new customers (2) Gov't Buyer (2) Spin-out Firm (2)	Integrate w/ Client or Strategic Partner (7) Firm / IP Acquisition (1)	Global Distribution (2)
Renewable Energy, Env Quality & Health (n=8)	Firm / Team Formation (4) Research (2) Prior Expertise (2)	Research (4) Engage Users / Identify Need (3) Firm / Team Formation (1)	Validate Env Mechanism (4) Test novel materials (2) Early Adopter (1)	Materials / Process Improvement (2) Gov't Buyer (1) Test and Validate Solution (1)		
Petrochemical (n=4)	Research (2) Prior Expertise (2)	Concept Dev / Prototyping (3) Firm / Team Formation (1)	Test Mfg. Scaling & Transfer IP (4)	Receive feedback from Industry (2)		
Agriculture (n=2)	Research (2)	Concept Dev / Prototyping (2)	Pilot Testing (2)	Scale-up Testing (2)	Market & MFG within firm (1) Targeted sales (1)	Global Distribution (2)

5.2 Urban Innovation Ecosystem, Map of Twin Cities by Sector

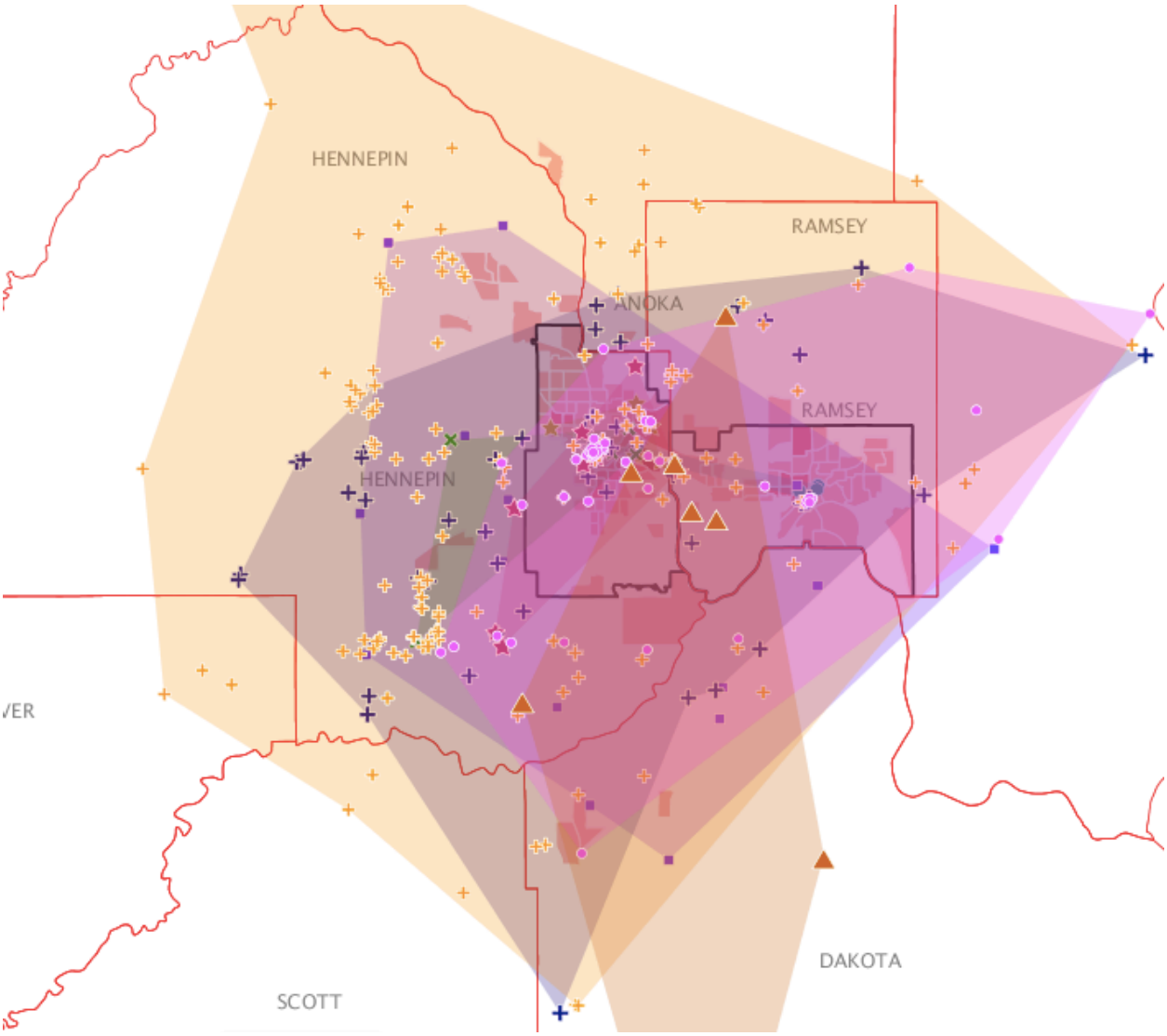
In the Twin Cities region, there are a few geographic areas in which organizations that directly and indirectly support technological innovation are clustered. There is a cluster of organizations in downtown Minneapolis as well as in Saint Paul that are connected by the I-94 highway. There is a high density of industrial firms in the Northwest of the metropolitan region at the confluence of I-94 and I-494, and along the corridor locally called "Medical Alley" that runs from Maple Grove, MN south along I-494 to Eden Prairie, MN in the southeast of the urban region. An online interactive map (see Figure 1 below) shows each organization and can be sorted by organization type. There are distinct areas where firms and organizations are located within the cities that make up the metropolitan region, but in Saint Paul and Minneapolis, historical zoning largely informs the distribution of firms. There are few organizations in northern and southern Minneapolis, and aside from a few industrial sites in eastern Ramsey county, most firms are located at the core of Saint Paul. However, in the surrounding towns and cities, large industrial sites and supporting firms, such as consultants and advocacy organizations, are more geographically dispersed. This finding suggests that innovation activities within the region are not concentrated in one particular location. Rather, organizations are spread far and wide across the metropolitan region with the exceptions of the downtown areas of St. Paul, Minneapolis and the "Medical Alley" corridor along I-494 from Maple Grove to Eden Prairie and along I-694 from Maple Grove to Maplewood.

Workshop Reflections

Workshop participants viewed this map and reflected upon the findings. The geographic range of organizations didn't reveal clear clusters. One participant felt that the shaded polygons, "are not the best way to show the pattern – there are several independent centers – the shaded area in between are largely residential." This was echoed by another participant who said, "You need to look at greater detail into the map, because of the residential pockets." Then we zoomed into specific areas on the map and participants identified the I-494 corridor to the west of Minneapolis and one person said, "So that is the corridor that they were telling me about." At a finer level, localized geographic patterns become more apparent as one participant pointed out, "The history around here is that greenfield sites were built up along the new highways. Look at [company] campus on I-94 or the new campus by [company] north of the city. Another example of historical factors is the absence of any industry in the south of Minneapolis, which is residential and the absence of firms was easy to observe. As one person said, "Everyone wants to live there, it is too expensive for commercial space anyway."

Then the discussion turned to the two clusters in the Twin Cities of Saint Paul and Minneapolis. One participant said, "There is a tug of war between the cities. I need to have offices, partners on both sides of the river. They are always trying to one up each other." Another person said, "Why are we competing with ourselves? We all know that if the company moves to either city, then the people will shop in the area, buy a house in the area. They won't just stay in Minneapolis." Another participant spoke up, "Ok, I am part of the problem here. I was born in Saint Paul and I want Saint Paul to succeed. If I invest in a company, I want them to move to Saint Paul." A participant working in economic development offered, "This is the problem. We don't have a sense of how we are growing this together. We didn't even have an organization to address this until they formed Greater MSP." Another person chimed it, "Isn't it the Twin Cities." The issue of how to brand and market the region with full cooperation from all cities, counties and businesses remains a challenge.

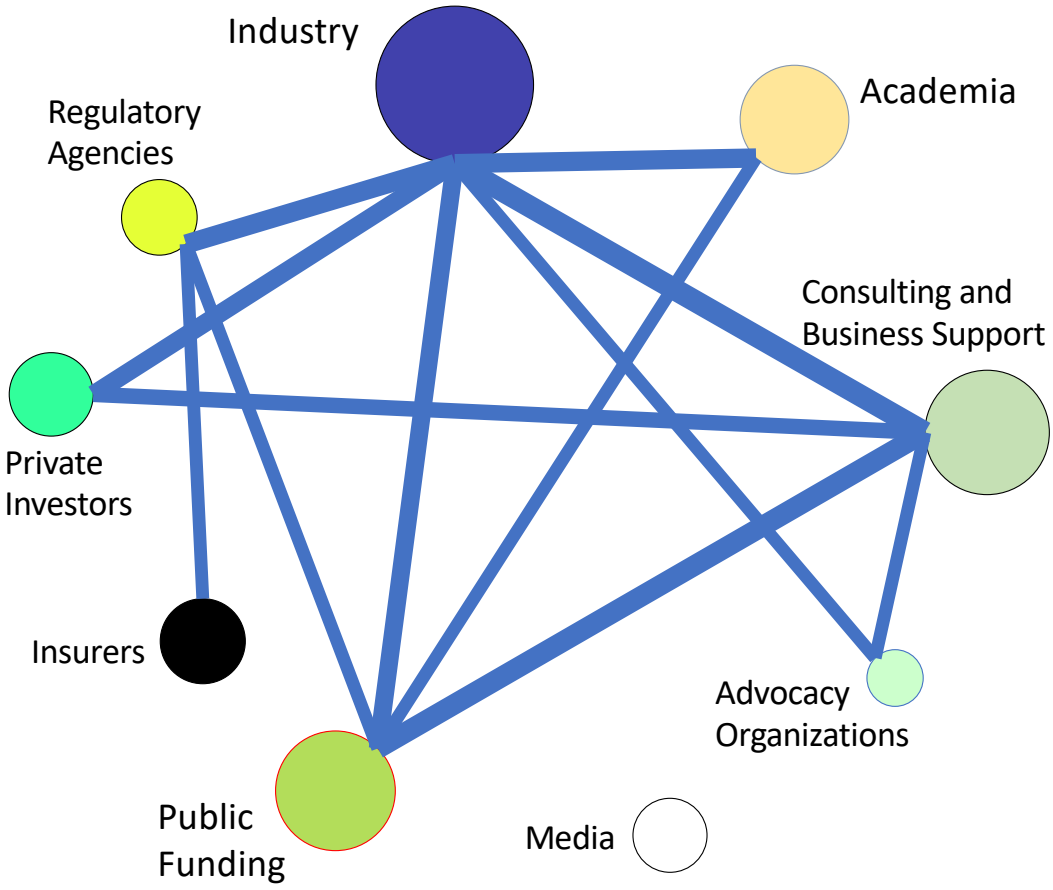
Figure 1. Innovation Ecosystem in Metropolitan Twin Cities. This map was populated with the ~550 organizations that were identified by the research team. The organizations were categorized into one of nine groups: academics, consultants, industry, insurers, investors, media, non-profits, public funders, and regulatory agencies. An interactive version of this map can be accessed at: https://worldmap.harvard.edu/maps/TwinCitiesEntrepreneurs/dzH



5.3 Stakeholder Network Analysis

The core organization types within the innovation ecosystem in the Twin Cities are industry, academic, and government funders and support agencies, see Figure 2 below. This is not surprising and neatly fits with the "triple helix" theory of innovation offered in the introduction to this report. These three types of organizations have strong connections to one another in terms of reciprocal mentions as reflected in underlying data tables, see Tables 3 and 4. Yet, academic organizations are only connected to industry and public funding agencies, and there was no evidence of strong connections to private funding, advocacy organizations, media, or consulting and business support organizations. Secondly, private investors, consultants and attorneys, and regulatory agencies are well represented and connected to the core organizations. Consulting and business support organizations have the second most connections behind industry, and are frequently mentioned within narratives on innovation. Consultants and legal firms are strongly connected to private and public funding organizations, and also have strong connections to industry. Those three second-tier organizations are well understood to support innovation and facilitate access to resources, knowledge, and relationships with other organizations. The least frequently mentioned organizations are insurers (connected to regulatory agencies), NGOs (connected to consultants and industry), and media (no connections to other organizations).

Figure 2. Network Analysis. The nine different organizational types are indicated with circles, while the lines indicate connections between the actor categories. Note: Circle size is proportional to the frequency of mentions by any actor, and line thickness is proportional to the reciprocal mentions between any two actors. The absence of a line means that the average reciprocal mention rate was smaller than one (<1.0) (see Table 4 below).



Workshop Reflections

Much of the workshop discussion centered around the isolation of the media and lack of references by interview participants to the media. The workshop participants felt that the network map offered, "no surprises" to them. Another participant stated, "It is a cultural attribute, we aren't focused on telling our story." Someone added, "What press? There are hardly any reporters left that cover business, let alone tech." Another participant said, "This reflects the reduction of media funding and the ability of large corporations to promote themselves." As one person summarized, "The media is impoverished. That is why there is no science or tech coverage."

Table 3. Directional Data Table for Network Analysis. This table shows all the mentions of other organizations, as well as self-referential mentions by the participants. The actor groups (left hand column) are listed and the number of participants that completed this portion of the interview is indicated in parenthesis (n =). The frequency of mentions is divided by the number of organizations to indicate the average frequency at which an actor is mentioned by another actor. The activity summary is the average frequency at which an actor spoke about any another actor and the passivity summary is the average frequency at which an actor was mentioned by any other actor. This data informs the size of the circles shown in Figure 2, above. Note: Actor categories are abbreviated in the table below, Ind = Industry; Con = Business Consultants and Attorneys; Ins = Insurers; Pvf = Private Funding; Aca = Academic; Pfo = Public Funding and Support; Reg = Government Regulators; NGO = Non-governmental organizations; Med = Media.

Actors	Ind (n=10)	Con (n=6)	Ins (n=1)	Pvf (n=5)	Aca (n=13)	Pfo (n=2)	Reg (n=1)	Ngo (n=2)	Med (n=2)	Acvitity Summary
Ind (n=10)	2.5	1.3	0.0	0.9	1.8	0.7	0.9	0.0	0.3	8.4
Con (n=6)	2.0	1.8	0.0	1.0	1.3	1.2	0.3	0.0	0.0	7.7
Ins (n=1)	1.0	1.0	4.0	1.0	0.0	0.0	2.0	0.0	0.0	9.0
Pvf (n=5)	1.8	1.4	0.0	1.6	0.4	0.6	0.6	0.0	0.2	6.6
Aca (n=13)	1.2	0.5	0.0	0.2	3.7	1.1	0.1	0.0	0.2	6.8
Pfo (n=2)	2.0	2.0	0.0	0.0	1.0	2.5	0.0	0.0	0.5	8.0
Reg (n=1)	2.0	0.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	6.0
Ngo (n=2)	2.0	2.0	0.0	1.0	0.5	1.0	0.0	0.5	1.0	8.0
Med (n=2)	1.0	1.0	0.0	0.5	1.0	1.0	0.5	0.0	2.0	7.0
Passivity Summary	15.5	11.1	4.0	6.2	9.7	10.0	5.4	0.5	5.2	

Table 4. Reciprocal Data Table for Network Analysis. This table shows the average reciprocal mentions between different organizations. The line connections between actors in the network analysis (see Figure 2) are generated from this data table. If the average reciprocal mention is below one (<1.0), then no line is shown in the diagram. Note: Actor categories are abbreviated in the table below, Ind = Industry; Con = Business Consultants and Attorneys; Ins = Insurers; Pvf = Private Funding; Aca = Academic; Pfo = Public Funding and Support; Reg = Government Regulators; NGO = Non-governmental organizations; Med = Media.

Actors	Ind (n=10)	Con (n=6)	Ins (n=1)	Pvf (n=5)	Aca (n=13)	Pfo (n=2)	Reg (n=1)	Ngo (n=2)	Med (n=2)
Ind (n=10)	2.5								
Con (n=6)	1.7	1.8							
Ins (n=1)	0.5	0.5	4.0						
Pvf (n=5)	1.4	1.2	0.5	1.6					
Aca (n=13)	1.5	0.9	0.0	0.3	3.7				
Pfo (n=2)	1.4	1.6	0.0	0.3	1.0	2.5			
Reg (n=1)	1.5	0.2	1.0	0.3	0.0	1.0	1.0		
Ngo (n=2)	1.0	1.0	0.0	0.5	0.3	0.5	0.0	0.5	
Med (n=2)	0.7	0.5	0.0	0.4	0.6	0.8	0.8	0.5	2.0

5.4 Aggregated Organizations – Top Ten

The social network data above suggests that industry, academia, and public funding agencies are at the core of the innovation ecosystem in the Twin Cities. This is reinforced by the top ten most frequently named organizations during the interviews. Large corporations and entrepreneurs are two of the most frequently mentioned organization types and this reflects an essential tension between small firms seeking to grow and larger firms that have the resources to manufacture, market, and engage in global sales. The prevalence of large corporations in medical devices, biotechnology, and ICT/IoT is widely recognized, and entrepreneurs in the region seek to develop new products that support those firms.

Faculty researchers and graduate students are also frequently mentioned, along with university contracting and technology transfer offices. Those three distinct stakeholder groups include the leading researchers whose careers are built upon developing novel approaches and tools for conducting research on materials at the nanoscale. The graduate students, however, are the principal labor force that conducts that work and performs the tests and experiments and executes on the research plans laid out by the faculty researcher. The universities' offices that administer external contracts and the technology transfer process are responsible for facilitating the relationships with industry. University leaders and administrators are not entirely absent from the stories of innovation, but they were not mentioned frequently enough to be in the top ten.

The funding and support for research is balanced between federal funding agencies and private funders, primarily venture capital and angel investors. The slight emphasis on federal funding agencies may indicate the emphasis on academic research, although federal funding includes small businesses seeking Small Business Innovation Research (SBIR) grants. Local entrepreneurs and growth businesses look to angel funders, with many commenting about the need to connect with the social networks that create access to those high-wealth individuals in the region. Given the emphasis on medical devices and biotechnology within the regional economy, it is not surprising that federal regulatory agencies were frequently named.

Table 5. Top Ten Organizations. The frequency at which organizations were mentioned is reported.

Organization	Frequency
Large Corporations	29
Faculty Researchers	23
Founders and Entrepreneurs	20
Federal Funding Agencies	20
Federal Regulatory Agencies	15
University Contracting and Technology Transfer Offices	14
Venture Capital	10
Graduate Students	10
Angel Investors	9
Media	8
Other	162

Workshop Reflections

During that discussion the workshop participants were not surprised, as one said, "This makes a lot of sense to me." Another participant said, "It makes sense that the local government is not mentioned much." As one workshop participant said, "This relates to a few things, there was an acquisition for

$300M and it was back page news, like no big deal around here. People think that Tennessee has a medical hub. No, they have a marketing branch in the government spending ten times what we do to tell their story." Although someone was surprised, "Why aren't the Launch MN grants mentioned in connection to the State or the Angel Tax Credits?" The conversation turned to high-wealth individuals and how to connect angel funders to entrepreneurs. One person chimed in, "The people that you are talking about, if they don't want to be found, they won't be found. Others that want to be seen? You can find them." The prominence of large corporations suggests their importance in terms of internal research and development and their role as an acquirer of smaller firms, which was a clear "exit strategy" for many entrepreneurs and investors. Given an extended list of all the organizations mentioned, one participant commented, "It is amazing that users or patients were only mentioned 7 times in the 49 interviews." The distribution of organizations mentioned fostered good discussion about the importance of different organizations.

5.5 Key Responsibilities for Top Organizations

The following lists shows the distribution of responsibilities held by the most frequently mentioned organizations in the Twin Cities. Participants involved in this study each assigned responsibilities to other organizations as well as to themselves. At first, the data may seem overwhelming and difficult to interpret. Yet, the important findings become evident when the organizations are viewed as a network. First, there is a broad range of responsibilities across these organizations, which indicates strong heterogeneity in the network. This means that in most instances, there is more than one organization that is responsible for an activity, such as economic growth or addressing diversity. Second, the responsibilities listed reflect profit-seeking values, as expected, but there are other core values stated, including storytelling and publishing, addressing diversity, and committing to the local values and region. The list below promoted high levels of deliberation within the workshop sessions and some of those statements are shared below. The responsibilities start to extend the metaphor of an innovation "ecosystem" by detailing the work performed by the different organizations within the Twin Cities. Much like an environmental ecosystem, an urban innovation ecosystem is comprised of various organizations that perform various interrelated activities that are differentiated and affect different outcomes.

The following lists shows the top ten organization types along with the most frequently mentioned responsibilities for each, with the number of respective mentions in parenthesis.

1. Large Firms
- Execute Mergers & Acquisitions (14)
- Grow profitable firm (12)
- Strategic plan for technology changes (11)
- Support internal R&D (9)
- Reflect values of city (9)
- Identify, hire, train talented employees (7)
- Support external R&D (6)
- Assess and mitigate risks of technology and protect environment & worker safety (6)
- Commitment to Diversity (5)
- Foster local supply chains (4)
- Communicate, tell stories of innovation (2)

2. Faculty Researchers
- Manage and conduct research (15)
- Pursue Entrepreneurship (10)
- Mentor / Advise Graduate Students (7)
- Develop Research Network (6)
- Publishing results (5)
- Secure Funding (3)
- Teach Classes (3)
- Service to the profession (2)
- Assess future unexpected properties of nanomaterials (2)
- Share results beyond academia gain broader visibility (2)
- Be inclusive and promote diversity (1)

3. Entrepreneurs & Founders
- Create strategic plan for growth and exit (9)
- Identify and hire talented people (9)
- Manage firm's finances and operations (9)
- Assess product-market fit (6)
- Secure investments for firm's growth (6)
- Invent and develop novel technologies (5)
- Reflect on and learn from failure and prior experiences (5)
- Keep company in MSP, grow ecosystem (3)
- Create things that will solve challenges facing society (3)

4. Federal Funding Agencies
- Funding research projects (14 mentions)
- Seed fund for American small business (9)
- Hold researchers accountable and perform oversight (5)
- Provide infrastructure for large-scale research (4)
- Defining research priorities (3)
- Support interactions between industry and academics (1)
- Demand roadmap for future of research developments (1)
- Funding research that is too risky for venture capital (1)
- Training students (1)
- Ensuring money addresses broader impacts (1)

5. Federal Regulatory Agencies
- Ensure drugs and devices are safe (7)
- Make regulatory decisions / approval (5)
- Communicate, give feedback (4)
- Issue guidelines and standards (3)
- Collaborative, help establish pathway (2)
- Review clinical data and processes (2)

6. University Contracting, Technology Transfer Offices
- Negotiate terms for contracts, licenses (10)
- File provisional, full patent applications (8)
- Facilitate networking for academics, industry, investors (3)
- Assess value of intellectual property pre-filing (3)
- Offer mentoring and training (3)
- Generate revenue to support operations (2)
- Encourage diversity in gender and backgrounds of entrepreneurs (1)
- Identify licensees (1)
- Fund / support early stage firms (1)

7. Venture Capital
- Identify and select deals that allow for reinvestment (8)
- Be mentors and advisors and good citizens in tech community (6)
- Cultivate network and share it with vested companies (4)
- Provide executive leadership (3)
- Be open to review entrepreneurs pitch (2)
- Be respectful and don't string entrepreneurs along / do some deals (2)
- Possess knowledge of product/sector (2)
- Understand entrepreneur's perspective (1)

8. Graduate Students
- Conduct laboratory research (10)
- Become entrepreneurs (8)
- Write and present research (6)
- Explore career opportunities (5)
- Manage research projects (4)
- Actively engage industry (2)
- Create novel prototypes (2)
- Teach classes (1)
- Learn (1)
- Write grants for professor (1)

9. Angel Investors
- Fund firms early on (4)
- Review entrepreneurs pitch (3)
- Help expand network of firm (2)
- Offer mentorship and advice (1)
- Perform due diligence prior to investing (1)
- Be honest about intent to invest or not invest (1)
- Have patience for 10yr returns (1)

10. Media
- Communicate stories about science and technology in Twin Cities (10)
- Attract external firms/people and promote MN innovation ecosystem (4)
- Critical review of technology impact on environment/people (3)
- Earn income from Ad revenue (1)
- Publicize events on gender equity (1)

Workshop Reflections

The range of different roles assigned to the top ten organizations was quite interesting and many participants validated that the assigned responsibilities were accurate. For one participant they felt that the responsibilities of venture capitalists are synergistic, "being mentors and cultivating network should turn into identifying and selecting deals." Another participant commented on the lack of frequency (2 mentions) that faculty researchers are responsible to, "share results beyond academia, gain broader visibility." They said, "Faculty need to link to media," which they saw as part of the solution to the lack of connection to media.

The discussion turned to the responsibilities for the university contracting and technology transfer offices. One person stated, "They are managing the process to hit the metrics that are set out for them. The question is, are those the right metrics?" Another participant stated, "There is a lot of double counting going on in that office." Some disagreed, "They are doing good work negotiating terms. There are good people there." The responsibility to "pursue entrepreneurship" among research faculty seemed high to the workshop participants. They felt that might reflect the bias of the sample, such that faculty that responded to an interview about innovation would be interested in entrepreneurship.

5.6 Fulfillment of Responsibilities

This section assesses the fulfillment level of the top ten organizations and thus offers what one participant called a "360 review" of each of these organizations. The following Figures 3 and 4 are supported by the data presented in Table 6. Participants assigned fulfillment ratings for other organizations as well as for themselves, with 1 being the lowest score (responsibilities not at all fulfilled) and 5 the highest score (responsibilities completely fulfilled). Graduate students, federal funders, and faculty researchers were assigned the highest mean fulfillment scores, meaning that those individuals and organizations are well regarded as compared to other organizations in the top ten. Local angel investors and federal regulatory agencies were also assigned relatively high scores. This reflects numerous sentiments about the positive contributions made by high-wealth individuals within the region. There are also strong working relationships between federal regulatory agencies and the organizations creating novel medical devices. The lowest scores were assigned to the media, venture capitalists, and university contracting and technology transfer offices. These charts were the subject of vigorous discussions among the workshop participants. The following section shares the constraints and barriers that are preventing these organizations from performing at higher levels.

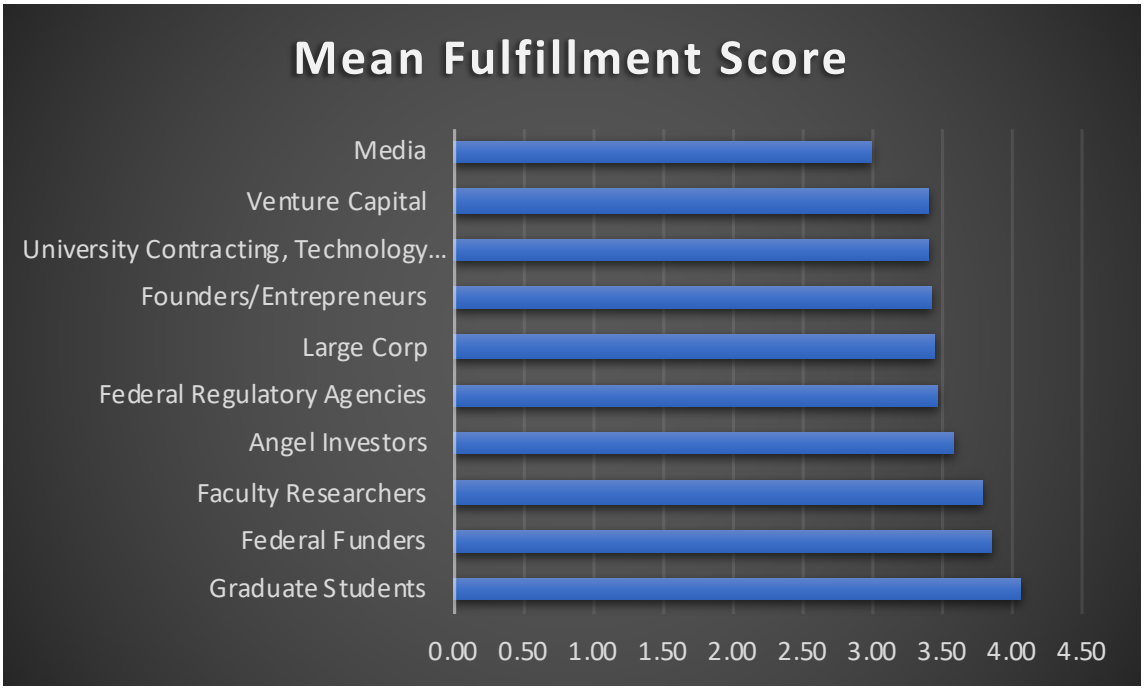


Figure 3. Mean Fulfillment Score. This graphic depicts the mean fulfillment score assigned to the top ten organizations mentioned. The fulfillment score assigned by participants to other organizations and to themselves was on a 5-point scale: 1=not at all; 2=slightly; 3=somewhat; 4=mostly; 5=completely.

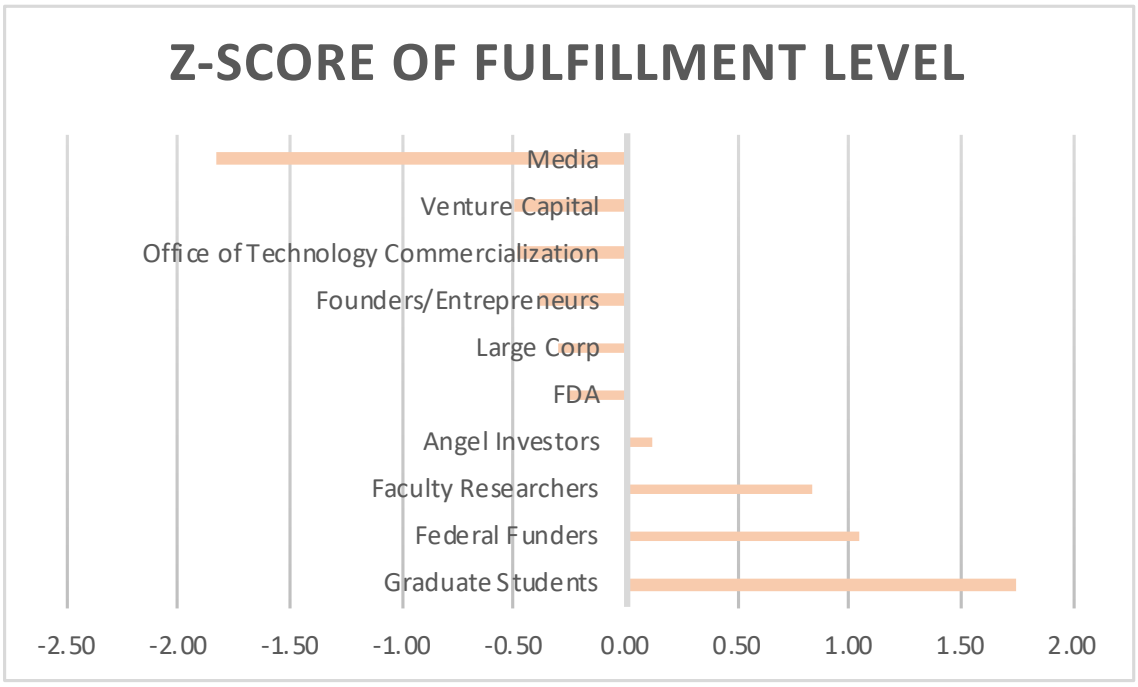


Figure 4. Z-Score of Fulfillment Level. This figure illustrates the differentiation between the organizations that scored highly (above 0) and those that scored lower (below 0). Note: Z-Score is a statistical value comparing a given measure to the mean of a group of values and is measured in terms of standard deviations from the mean.

Table 6. Fulfillment of Responsibilities. This table reports the mean fulfillment score assigned by participants to other organizations and to themselves (1=not at all; 2=slightly; 3=somewhat; 4=mostly; 5=completely). The mean fulfillment scores were then analyzed using a z-score. Note: Note: Z-Score is a statistical value comparing a given measure to the mean of a group of values and is measured in terms of standard deviations from the mean.

	Organization	Mean	Z-Score
1	Large Corp	3.45	-0.30
2	Faculty Researchers	3.78	0.84
3	Founders/Entrepreneurs	3.42	-0.39
4	Federal Funders	3.84	1.04
5	Federal Regulatory Agencies	3.46	-0.25
6	University Contracting, Technology Transfer Offices	3.39	-0.49
7	Venture Capital	3.39	-0.50
8	Graduate Students	4.05	1.75
9	Angel Investors	3.57	0.12
10	Media	3.00	-1.83

5.7 Constraints and Barriers for Top Organizations

Participants involved in this study stated constraints and barriers either internal or external to the mentioned organizations. They each expressed constraints and barriers for other organizations as well as for their own. These data, when layered on top of the previous findings, point to areas that require the time and attention of civic leaders who are promoting technology-based innovation. While the scope and boundaries for this study are limited and temper the findings, the data suggest opportunities for investment, greater programmatic development, and strategic planning.

Based on the constraints identified by the interview participants, large firms need to develop longer-term strategies in technology and innovation, a problem which was compounded by shifts in corporate leadership. Those changes in leadership create shifts in strategy, which was often discussed as including the research investments that are “pet projects” of executives and those projects do not last beyond their tenure within the executive suite. Further, large corporations are seen as isolated and standing apart from smaller firms and broader stakeholders. Similarly, entrepreneurs need to focus more on business strategies and avoid obsessing over technical perfection. At times, entrepreneurs are neither responsive nor open to advice, which leads to an inability to pivot and adapt products to fit the market need. Entrepreneurs in the Twin Cities are also likely to hire their friends rather than evaluating talent from the broader labor pool, which can result in unconscious bias during the hiring process. This was frequently discussed as the “Bro Culture” among entrepreneurs.

Among the academic organizations, different units faced different challenges. Faculty researchers are often limited in the scope of their research and stay within the safe confines of their research domain. While they are deemed to be overcommitted, many outside the university found it hard to connect to faculty and discussed the challenge of navigating the extensive bureaucracy in universities. Faculty researchers self-reflected upon their experiences in business and acknowledged they lack expertise.

Even the most prolific faculty researchers, in terms of start-ups, talked about the value of business partners to take their research into the market. They are generally not good at conveying research to the outside world beyond their specialized domain or discipline. Graduate students, who were highly ranked in terms of fulfillment, suffered fewer critiques. A few participants discussed the lack of intellectual engagement that may plague some graduate students, along with frustrations about lacking "people skills" to complement their technical skills. As far as the university contracting and technology transfer offices, the primary critiques were about inefficient processes and the time required to conduct business with their offices. There was a sense that faculty researchers dominated the process and that the organization was hesitant to irritate prominent faculty.

Venture capital, while present in the Twin Cities, is not focused on technological development, and rather is concerned with software and quick exits rather than manufacturing products that can take upwards of a decade to pay off. There appears to be a lack of strategic thinking and mechanisms to invite venture capital into the Twin Cities with most people opting to "jump on a plane" and go to them. Local angel investors were seen as inaccessible by some participants. One public narrative by a leading technology entrepreneur in the region offered a vignette, "you just need to visit the [country club] bar after 5pm and talk to the right people and you could walk out of there with millions." Moments later, in the audience, a woman stood up and said, "I was at [country club] and we made a lot of money together. Let me know when you want to do it again." There were only two mentions that local angel investors lack resources. Rather, there is an abundance of high-wealth individuals and the challenge is engaging in their social network and convincing them that technological investments can return profits. Many are, understandably, traditional in their investments.

The following list shares the top ten organizations and the most frequently mentioned challenges for each, with the number of mentions in parenthesis. Selected quotes have been included to give more tangible examples.

1. Large Corporations
    - Lack of Strategy (13 mentions)
    - Lack of Outside Engagement (11)
    - Management / Personnel (7)
    - Internal Issues (6)
    - Poor Communication (4)
    - Short-Term Interests (4)
    - Slow Moving (4)
    - Risk Averse (2)

2. Faculty Researcher
    - Limited Scope (11 mentions)
    - Overcommitment (7)
    - Poor Communication (6)
    - Poor Decision Making (5)
    - Lack of Business Sense (5)
    - Barriers to Entry (5)
    - Time Management (4)
    - Self-Interested (4)
    - Lack of Resources (3)

3. Entrepreneurs / Founders
    - Lack of Strategy (7 mentions)
    - Not Open to Advice (5)
    - Risk Aversion (5)
    - Product Development (4)
    - Lack of Experience (3)
    - Lack of Resources (3)
    - Lack of Talent (3)
    - Bro Culture (3)

4. Federal Funding Agencies
    - Inaccessible (8 mentions)
    - Resources (8)
    - Poor Discernment (4)
    - Bureaucracy (4)
    - Risk Averse (3)

5. Federal Regulatory Agencies
    - Slow (5 mentions)
    - Lack of Experience (5)
    - Unlevel Playing Field (4)
    - Bureaucratic (3)
    - Expensive (2)

6. University Contracting and Technology Transfer Offices
- Inefficient (7 mentions)
- Dominated by Faculty (5)
- Lack of Strong Procedure (4)
- Poor Support Outside Big Firms (3)
- Poor Communication (3)
- Lack of Strategy (2)
- Resources (2)
- Personnel (2)

7. Venture Capital
- Self-Interested (4 mentions)
- Lack of Resources (3)
- Lack of Strategy (3)
- Lack of Presence (2)

8. Graduate Students
- Intellectual Engagement (6 mentions)
- Skills Development (4)
- Personal Development (3)
- Communication (2)
- Accountability (2)

9. Angel Investors
- Inaccessible (5 mentions)
- Risk Averse (3)
- Resources (2)
- Inactive (2)
- Short Term (1)

10. Media
- Inaccessible (6 mentions)
- Quality of Stories (4)
- Lack of Platforms (3)

Workshop Reflections

The challenge that large corporations had, "too few skunkworks teams working on projects" was an "insightful" finding about the constraints facing large corporations. Others, felt that there just needs to be more balance and strategic consideration for internal investments versus external acquisitions. The responsibilities for the large corporations were largely understood, but one person stated, "I am surprised that 'risk averse' was only mentioned twice, that should be higher." The challenge facing entrepreneurs associated with "Risk aversion" was supported by one participant who said, "[They have] comfortable corporate work environment, why move." Another participant felt that what was missing from the list of constraints facing entrepreneurs was, "The lack of a vibrant network of other entrepreneurs, that is what is missing." That sparked a conversation about how to foster that network.

A participant was amazed that "Lack of Resources" was the least frequently challenge listed for faculty researchers and it suggested to one workshop participant, "[University researchers are] well-resourced in this area, especially Chem, Biomed and Eng." The discussion shifted to the challenges facing university contracting and technology transfer offices. The constraint that faculty 'dominated' the process was questioned. One participant offered, "Faculty don't trust them and this is a State based upon trust. There is a feeling that they are just working towards metrics" Another participant felt differently about the influence of faculty on the technology transfer process, "That's a good thing" and they didn't see it as a challenge or constraint. It was discussed that ongoing leadership changes were creating challenges, which were not accounted for in the interview data.

The lack of accessibility that was mentioned for Angel Investors was understood to relate to persons outside the "right social circles." One participant noted that graduates from a local Masters of Business Administration program are highly influential. The lack of risk taking to become an entrepreneur was according to one workshop participant, "interesting because Medtronic started in a MN garage, however, that was well before the advent of the FDA". One participant stated, "We have angels and there are some large primary and secondary venture funds here. What we are missing are the $10-50M or midscale funds that can help scale firms." Another participant refuted the notion that angel investments are "short-term" and with only one mention, that statement does not reflect a consensus among the interviewees.

The media in the Twin Cities, which has been transformed by the emergence of online news organizations, was perceived as inaccessible and issuing stories that lacked depth. As one successful

entrepreneur said, “I could get press in the New York Times but the local papers didn’t print anything about us.” As another participant reflected, “The [paper] used to have [reporter]. She is gone now and I don’t think they have replaced her. That is a loss for the whole community. Who is going to pick up that slack?” One participant offered that the lack of quality stories in the media was related to a lack of “scientific literacy.” Another participant stated, “Why are there so few critical reviews of technology impacts on environment/people? Is this not what a general population would be able to identify with?”

6.0 Key Takeaways

The closing points of this report are divided into the positive assets that emerged from this research and the deficits and challenges that face civic leaders in the Twin Cities. The comments below are brief and supported by representative quotes to emphasize and clarify the meaning. This research in no way aims to be negative, rather, it offers a reflection on the current state to civic leaders in the Twin Cities. The findings may offer insights to other cities that are aspiring to cultivate a vibrant innovation ecosystem. The job of the analyst in this research is to bring clarity to that reflection, even while understanding that there are myriad perspectives.

6.1 Key Assets

Small Business Support is Emerging

There is a growing set of resources for new and existing technology businesses. From formation to expansion, the Twin Cities is starting to cultivate programs that support entrepreneurs. Efforts in the private sector and universities are well attended and have high levels of engagements.

> “Ten years ago, we didn’t have places like [Accelerator] and there was far less support for local entrepreneurs.”

Network Centered Around Large Corporations

Large organizations dominate the local innovation ecosystem and the network extends through the supply chains and through mergers and acquisitions. Given the centrality of the large corporations, the regional innovation ecosystem might seek to invest in growth-oriented small businesses. Further, the large corporations need to explore how they can best engage with stakeholders across the region.

> *”You build it with an eye towards who will buy your company. We need to get it to a place where they will step in and we can cash out.”*

Strong Foundations and Philanthropy

There are numerous foundations with deep roots in the Twin Cities that are committed to the growth of world-class research, healthcare, and economic development. The foundations that have long supported the arts and science museums as well as educational programs need to evaluate how they want to engage with technology-oriented efforts. There are opportunities for foundations to take on a range of issues from diversity and education to goal-oriented innovations that address the community’s needs.

"There are traditions here about how things are done. And part of that is the commitment of the local companies to the non-profits and from the non-profit foundations to the research community."

"You can't have world-class medical device development without relationships between the hospital, researchers, and firms. They funded that program, […] it is part of what makes it work here."

Strategic Collaboration

There are a number of organizations that are tightly coupled and work closely on strategic technology development projects. The long-term relationships built upon trust allow companies and organizations to closely partner and solve problems. Those relationships have yielded novel medical devices, semiconductors, and manufacturing processes that are highly complex and proprietary.

"[Corp.] invests in us and we provide them with excellent research. And they get to sort of interview the students and many get hired there."

"We make machines and tools that can manipulate matter in ways that are unparalleled; of course we want to partner with [university] and have them publish results that require our machines to achieve."

"That is what it is built upon: trust. If you didn't have that, I don't know how it would get done."

6.2 Key Deficits and Challenges

Lack of Cohesion in the Twin Cities

The competitive spirit between the cities in the region makes attracting new firms to the region challenging. Many suggested that the high level of regional competition was harmful to efforts to build a cohesive narrative about innovation in the region. The large corporations within the region are more concerned with building their brand than acknowledging that they are headquartered in the Twin Cities.

"They don't get it. If someone flies in to look at relocating here, the region benefits. It doesn't need to be a competition between [city] and [city] or [county] and [county]. The new employees will live in different places and shop here and there.

"We didn't have any sort of a regional marketing plan before the Amazon bid came out. I mean we didn't have any marketing material that was shared [between the cities]."

"It is hard to tell the story of innovation here because everyone wants to claim it as theirs, and they don't understand that it is bigger than their company or city. I mean, have you seen those new ads? They don't mention the place, just the company."

Cultural Constraints: Minnesota Nice & Humility

There is a set of cultural traits that are perceived to have unintended negative consequences. During the interview series, participants would address cultural attributes in passing. Many cultural attributes

including long-lasting relationships, trust, hard work, and perseverance were acknowledged as very positive assets. However, a few were noted as drawbacks by the participants themselves. When this was discussed in the workshop, one participant noted, *"If we think this finding is wrong, we wouldn't say that to your face. We will just talk bad behind your back."* That form of indirect feedback was seen as undermining the efforts of entrepreneurs. The other challenge centered around humility in a global context where "tech hype" gets the funding deals and attracts investors from California.

> *"They don't want to be mean to [entrepreneurs], so they don't tell them no and so they think there is a chance. The lack of direct feedback wastes their time and ours."*
>
> *"Some would say we are too humble to do a good job of telling our own story. We aren't good at bragging and so we are under the radar."*
>
> *"Have you heard of MN Nice? [response]. It can be a problem for us. It is about quiet confidence, but you talk to a SF VC and you need to really sell it."*
>
> *"If anyone rating themselves a 5 on that score, then check their ID. They aren't from here. There is always room for improvement."*

Investors and Business Model

There are some strong technology-based success stories, but there have also been a few failures that eroded the investor base. There is greater experience in traditional investments, debt lending, retail, and business infrastructure. Locally, a few failures in the medical device sector negatively impacted the investor community right around the time that the 2008-2009 macro-economic downturn occurred. Three venture capital and investment firms were interviewed and they couldn't name one firm based in the Twin Cities within their portfolio, meaning locally-situated investors survey the broader landscape, rather than the local landscape.

> *"When that investment failed, I would say 90% of the investors walked away and they haven't come back. There just isn't an appetite for that long-term risk associated with [biomedical] devices. If they are investing, it is in software."*
>
> *"Many of the rich folks are rarely in town, they are at the cabin or down south for the Winter. There aren't many that want to do the research and make investments in tech."*
>
> *"I am embarrassed. I want to tell you story about a local investment. We just don't have any. I am doing deals in California, North Carolina, New York. I just don't see enough coming out of the Cities. I am not going to make a bad investment just to have a local firm on the books."*

Technology Transfer

There seems to be a real constraint for many organizations that want to license, contract research, or enter into partnerships with the university. There have been changes in the management and leadership within the offices that handle technology transfer, and some participants were concerned that simplified metrics were driving the decision-making process. Others felt that faculty researchers were given too much power during the process.

> *"It can be ridiculous. The rules change every time I talk to them."*

"They don't understand the value of the intellectual property or they ask the same couple of firms and they say no. Then they don't patent it and then the firms swoop in."

"I waited three years and then they told me it wasn't worth it to patent. I am planning to start a company next year and we will patent it outside the university; they passed on it, so I will try and take if forward. I mean, I know the [government agency] wants to buy it, they paid me to build it."

Legislative Orientation

Local business associations are positioned to liaison with firms and to facilitate their interactions with the local, county, and state governments. The legislature does not consistently support entrepreneurship in the technology sector. The government's support for technology-based firms has been more traditional, supporting infrastructure investments and handling registration and regulatory matters. In the year's leading up to these interviews, the legislature had enacted an "Angel Investor" tax credit, but it was not reauthorized in 2017.

"We had an Angel tax credit. It had crazy rules, but it was there. Now it is gone."

At the time the interviews were conducted, state appropriations were in negotiation and the "Angel Investor" tax credit was back on the agenda.

"There is a proposal by DEED for some money, but they think that businesses will just appear. They need to think more long-term."

"The angel tax credit program has had some real impact on stimulating early stage venture investment, although its availability has been sporadic over the years."

NOTE: The 2019 proposal by DEED was approved after the interviews were completed in 2019.

Diversity and Inclusion

Technology innovation within the Twin Cities remains predominately skewed to white males. This problem is not hidden, nor did participants avoid it during the interviews. The issues associated with attracting and retaining diverse populations is widely recognized, yet it remains a challenge. The gender divide was mentioned overwhelmingly by female participants (12 of 18), who mentioned issues related to gender equity in both negative and positive ways. At one local technology conference, numerous panels were dedicated to gender equity in technology training and management training.

"The big companies are trying to attract a diverse group of people and doing a good job, but more leave than arrive. It is hard to address."

"We know the numbers, but the question is how to change it."

"The big companies have the HR programs and mentorship programs. It is the smaller ones that have the bros."

"They don't realize that by focusing social activities around alcohol, they are excluding people."

7.0 Future Research and Closing Thoughts

This study, while focused on the Twin Cities, will be compared to other cities in the United States that are working to foster technology innovation. In the months before arriving in the Twin Cities, I traveled to

metropolitan Atlanta in Georgia. There, I completed a comparable set of interviews and later conducted a workshop with those participants. That research will be directly compared to the findings from the Twin Cities, and similarities and differences will be identified. This research is distinct, as it doesn't rely upon economic measures of success. Rather, it accounts for stakeholder perspectives of the innovation ecosystem from the ground up and invites people involved in the creation of novel technologies to share their stories and to reflect upon their responsibilities and the responsibilities of other organizations within the city.

This approach might well serve to highlight gaps in the current innovation ecosystem that would not be identified by simply counting the number of university graduates or venture capital dollars secured. The aim of this research is to facilitate reflection among civic leaders and to help them identify the assets and deficits present in the innovation ecosystem. For the Twin Cities, the growth and expansion of large corporations that are built upon research and development has long served the region. As civic leaders look toward the future, there are opportunities for the region to unite around shared values and interests.

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