Rural Broadband and Advanced Manufacturing: Research Implications for Information Studies

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Abstract. Advanced manufacturing (AM) is a vital driver of the U.S. economy. AM is also crucial in building U.S. competitiveness by strengthening the scientific and engineering enterprise and providing transformative science and technology solutions. AM anchors rural economies across the country and is especially important to rural America, where it accounts for a larger share of employment and earnings than in urban areas. Broadband Internet connectivity is essential affordance of the "smart" AM production technologies key to U.S. leadership because they enable manufacturers to precisely customize products and supply for increasingly segmented markets. However, our review of policy and research suggests that little is known about the extent to which the U.S. broadband environment can support and enable AM, especially in the prime rural locations. In this paper, we will explore rural communities' AM readiness. Specifically, we synthesize research and policy documents relating to the centrality of broadband Internet to AM; the state of broadband in rural communities; and the potential for AM transform rural communities. We conclude with promising directions for information science researchers to further investigate the relationship between broadband and the potential for AM to benefit rural communities' economic potential.

Keywords: Advanced Manufacturing (AM), Broadband, Rural Communities

1 Introduction

According to the National Science and Technology Council (2013), advanced manufacturing (AM) is a key driver of the U.S. economy because it will produce high-income jobs and generate technological innovation. Furthermore, AM is crucial in building U.S. competitiveness by strengthening the scientific and engineering enterprise and providing transformative science and technology solutions (National Science and Technology Council, 2013). Traditional manufacturing is the process of converting raw materials into a finished ready-to-sell product through the use of manual and/or mechanized transformational techniques. The end goal of traditional manufacturing is to add value to achieve the objective. Advanced manufacturing, on the other hand, typically involves manufacturing processes in specific industries such as aerospace, medical, pharmaceutical, etc., while using advanced techniques and equipment for production and logistics. A fundamental goal of advanced manufacturing is to

produce products in the least amount of time while minimizing wasted materials and time (Bonvillan & Singer, 2017). In AM, high speed, uninterrupted broadband Internet connectivity is an essential affordance for technologies such as 3D printing (Petrick & Prindible, 2014); for this reason, broadband is a crucial enabler to successful U.S. competition reliant upon "smart" production to customize products and supplies for increasingly segmented markets (Bonvillan & Singer, 2017).

The manufacturing sector anchors rural economies across the country and is especially important to rural America, where it accounts for a larger share of employment and earnings than in urban areas (National Science and Technology Council [NSTC], 2018). Changes in manufacturing disproportionately affect rural communities. Over 70% of all manufacturing-dependent counties are non-metro (rural) and contain nearly a quarter of the United States' rural population (USDA, 2017). Although the earnings gap between urban and rural manufacturers is large, median earnings for manufacturing is still the second largest in rural counties (USDA, 2017). However, our review of policy and research suggests that little is known about the extent to which the broadband environment in the United States can support and enable AM in rural areas. In this paper, we explore rural communities' AM readiness. Specifically, we will examine the extent to which rural communities can provide broadband engage in AM's economic and social benefits. We will conclude with promising directions for research.

2 Rural Communities and Advanced Manufacturing

A robust American manufacturing base remains vital to maintaining America's economic strength and national security in the 21st century (Yudken, Croft, & Stettner, 2017). In line with this trend, the National Science and Technology Council (2013) identified AM as a critical driver for long-term economic prosperity and growth for the U.S. economy in regional, state, and local economies, especially in rural communities.

A recent survey of rural manufacturers revealed that the more rural the manufacturer, the more likely cost reduction and employee recruitment were challenges coupled with fewer growth opportunities and financing. The quality of specific nearby services and providers--broadband was chief among them --has disproportionately impacted rural manufacturers (Thomas & Campbell, 2018). Although rural manufacturers are different demographically, face different challenges, and have different needs, they delivered the same level of economic impacts and even higher amounts of additional investment. This positive effect is likely due to rural manufacturers being slightly larger on average compared to urban manufacturers (Thomas & Campbell, 2018).

The federal government supports programs that are specifically tailored to increase the strength and resilience of the manufacturing sector in rural regions. USDA programs provide a comprehensive support system for rural prosperity, including many programs that are also important to AM, such as STEM education, workforce development, rural infrastructure, and grants and loans for businesses and research organizations involved in rural development (National Science and Technology Council, 2018). USDA provides many programs that support AM and features expanding rural AM capacity as a plank of its strategic plan (National Science and Technology Council,

2018). For example, the Rural Business-Cooperative Service, a U.S. Department Agriculture program, provides technical assistance and financial support for rural manufacturers developing innovative value-added agricultural products for broader markets. Also, the USDA recently signed a Memorandum of Understanding (MoU) with Small Business Administration to advance federal support on providing timely access to capital and other forms of business assistance. This MoU aims to improve capital access to rural areas, increase the benefits of the Tax Cuts and Job Act of 2017, and improve technical assistance and infrastructure (National Science and Technology Council, 2018). These programs operated by the U.S. Department of Agriculture are critical for supporting manufacturers in rural communities and expected to help strengthen AM in rural areas.

Currently, there is the national call for states to undertake bold initiatives in a revitalization of the manufacturing sector (FloridaMakes, 2016). For example, the State of Florida is seizing upon current opportunities from global economic trends, re-shoring, and a desire for technological advancements to encourage AM companies to locate in rural communities (FloridaMakes, 2016). Especially in rural Florida, competitiveness and sustainability of the manufacturing sector are essential to ensure job growth and economic prosperity. As there is renewed national interest in manufacturing research and education, AM is creating an opportunity for the state to undertake bold initiatives in a revitalization of the manufacturing sector. The most significant innovation is expected to be coming from AM's diverse and growing range of technologies (e.g., nanotechnologies, robotics, sensors) because they generate higher productivity, require more highly skilled workers who are paid higher wages than other manufacturing sectors (FloridaMakes, 2016).

Moreover, the Advanced Manufacturing Institute at Kansas State University College of Engineering has been helping university faculty to connect with manufacturing industry that is in rural parts of the state. Along with their university faculty, they also have engineers and technologists that are devoted to this task. The Advanced Manufacturing Institute also has been seeking ways to help its rural industry partners connect to resources and expertise and things that they do not typically have access to because of their location; industries such as wood pellet manufacturing (Kansas State University, 2018).

3 Broadband and Rural Communities

3.1 Rural Broadband Challenges

Having access to the broadband Internet has become indispensable for the development of communities in the 21st century, especially in rural areas. With broadband Internet, rural communities can benefit in many ways, including attracting new businesses, enabling access to telemedicine and low-cost online education, searching for jobs online and having access to more government information through E-government. Consequently, both the federal and local governments are working together to increase broadband adoption in rural areas. To expand broadband infrastructure, more than $260 billion has been invested by both public and private sector since 2009 (Council of

Economic Advisers, 2016). Former President Obama also promised that the U.S. government would make fast and reliable broadband available to more Americans at the lowest possible cost. Initiatives like ConnectED and ConnectHome were designed to expand broadband access to more schools, libraries, and families across the United States (Council of Economic Advisers, 2016).

However, even with a constant effort to improve rural broadband access through various initiatives and programs by the government, many rural Americans still lag behind urban counterparts in broadband access. According to the Federal Communications Commission (FCC), the current standard for broadband service is at least 25 megabits per second downloading and three megabits per second uploading. This standard is considered adequate to stream video and participates in other high-traffic online activities (Strover, 2018). The *2018 Broadband Progress Report* stated that 31% of rural Americans still lacked access to broadband service that met the FCC standard, as compared to only 2.1% of Americans who lived in urban areas (FCC, 2018). These statistics show that the digital divide between urban and rural is remains significant and difficult to dispel. A main reason why rural areas are falling behind urban areas is the high costs of deployment. Internet providers must expect a high rate of adoption before they invest and for that reason, they focus their investments in urban areas where there are high-income consumers and high residential densities that maximize profits. Subsequently, both wired and wireless connections in rural areas are still comparatively worse than in cities. Overall, rural Americans have low-quality Internet service but pay higher prices when they are earning less than Urban residents (Strover, 2018).

Wireless technologies, including satellite, radio links, and mobile data are ways to increase the coverage area and adoption rate in rural America (Strover, 2018). Unfortunately, these technologies are not a complete solution either because their connections are still not reliable in rural areas and they are limited to consumer level applications like email, web browsing, and low-level data exchanges. These connection types are vulnerable to weather fluctuations and often require people to be within the coverage area of service towers. As many rural areas still lack access to broadband, the role of community anchor institutions such as public libraries is becoming more critical. Many people in rural areas who cannot afford broadband use free Internet connections offered by local public libraries (Stover, Whitacre, Rhinesmith & Schrubbe, 2017). These connections, though limited, have become alternatives for many rural community residents who do not have access to broadband Internet service. In this way, broadband is important to rural AM on two levels: 1) at the industrial level, reliable connectivity is important for myriad production processes; 2) at the human level, broadband attracts and supports a skilled workforce that can collaborate, manage logistics, and engage in ongoing training (Raveyre, 2011).

3.2 Federal Policy Efforts

The Trump administration has been addressing the importance of expanding broadband infrastructure and service to rural America ever since it came into power. As part of President Trump's promise to rebuild rural America, the Department of Agriculture announced that it would invest more than $200 million to help bring broadband to rural

communities (White House, 2018). Moreover, on January 8, 2018, President Trump signed two rural broadband executive orders that will reduce bureaucratic barriers preventing new broadband infrastructure from being built. The first executive order gives private companies access to infrastructure on government-owned land such as radio towers. The second executive order is about a plan to reduce the unnecessary government paperwork to get permission to build broadband infrastructure in rural areas (White House, 2018). The Trump administration expects that these efforts will streamline broadband in rural America.

Nevertheless, many rural broadband advocates remain skeptical of President Trump's policy because it appears to be insufficient to solve the real problem for broadband in rural areas (Levin 2018; Reardon 2018). In previous studies, researchers have identified the high cost of deployment as the main reason why broadband adoption is low in rural America. Installing fiber across miles of remote countryside costs a lot of money for telecom companies, and there is no sufficient way to make profits from it. President Trump's two rural broadband executive orders and USDA's $200 million investment are insufficient to solve this problem. The Trump administration would need to provide real solutions, like giving grants or infrastructure budget to expand broadband service in rural areas (Levin, 2018).

4 Rural Broadband's Importance to Advanced Manufacturing

Digitalization has been transforming manufacturing globally in the 21st century. The digitalization of manufacturing is changing how products are designed, fabricated, used, operated and serviced. In the same way, broadband is transforming the operations, processes, and energy footprint of factories and supply chains (Ezell, 2018). The application of information technology (IT) to every facet of manufacturing in industries as diverse plastics, wood pellets, and biomedical allows many entrepreneurs and creative service industries to view the low land costs in rural communities as viable company sites (Conley & Whitacre, 2016). Broadband affords rural manufacturers the ability to implement innovative processes, enable flexible workforce and training solutions, and manage complicated supply and delivery chains (Raveyre, 2011).

The advent and maturation of many technologies are driving AM. These technologies include: cloud computing; the Internet of Things (IoT); advanced sensor technologies; 3D printing; industrial robotics; data analytics; machine learning; and wireless connectivity that better enables machine-to-machine (M2M) communications (National Academies of Sciences Engineering & Medicine [NASEM], 2017) For these technologies, the combination of sensors and software into the Internet of Things is critical. In the AM context, "IoT refers to the use of sensors in production equipment (e.g., robots, stampers, actuators, 3D printers, computer numerical control [CNC] machines), and the products they make (such as jet engines, gas turbines, radiological equipment, or vehicles) to enable a real-time flow of information about the operational status and condition of the equipment or product" (Ezell, 2018, p.2). With these functions and capabilities, IoT will help manufacturing enterprises with real-time intelligence about their production processes and bestow them with the information needed to make better

operational and production decisions. Eventually, it will lead to the overall improvement of operating efficiency in manufacturing execution systems, warehouse management and control systems, and transportation management systems deployed in shop floors and warehouses (Ezell, 2018; Kim & Orazem, 2017).

Factories must have reliable broadband connectivity to make this happen, especially in rural areas near metropolitan communities (Mack, 2014). Broadband connectivity is key to the success of most successful rural industries (Atasoy 2013; Kuttner, 2012; Raveyre, 2011). IoT sensors need to interact and communicate with each other so that they can create the information streams upon on which AM techniques rely. For this reason, the Internet connection that IoT relies on needs to be stable and fast, which is why broadband connectivity is crucial and why concerns about the White House commitment to direct investments in community and commercial infrastructure that supports rural economies, including broadband high-speed Internet connectivity are so significant.

5 Areas for Further Research

The relationship between broadband availability and the potential for AM to transform rural communities offers several opportunities for information science researchers. Promising exploration areas and initial lines of inquiry foreshadowed by our synthesis include:

1. What sorts of needs assessments to rural community and AM industry leaders require to make informed decisions about the suitability between rural locations and AM production needs (Conley & Whitacre, 2016; NSTC, 2013; 2018)?

2. In rural communities that have successfully attracted AM companies, how did Internet connectivity play into the companies' decisions to locate in the community? How has the presence of the advanced manufacturer affected broadband availability for citizens and other businesses? In what different ways has AM changed the community (Conley & Whitacre, 2016; Raveyre, 2011)?

3. What sorts of competencies are required for AM workers to maintain Internet-enabled production (Mardis & Jones, accepted; Mardis, Jones, & McClure, 2018; Oh, Mardis, & Jones, accepted)? To what extent are AM technician training programs in rural communities imparting the necessary skills (Jones, Pahuja, & Mardis, accepted; Mardis, Jones, & Bouvin, 2018)?

4. Rural communities in other countries, such as China, Germany (Renden Schneir & Xiaong, 2016), and Scotland (Townsend, Wallace, & Fairhurst, 2015), have successfully addressed broadband Internet connectivity. To what extent has a relatively stable and established Internet infrastructure worked to attract AM employers to these rural communities?

5. Are there differences between the types of rural communities that have the potential to benefit from AM? For example, do rural, remote communities stand to help in the same ways and to the same extent that rural communities adjacent to metropolitan areas (Raveyre 2011; USDA, 2017)?

6 Conclusion

In this paper, we provided a synthesis of research and policy relating to the centrality of broadband Internet to AM; the state of broadband in rural communities; and the potential for AM transform rural communities. Taken together, the studies we reviewed suggested that while rural communities could significantly benefit from the influx of highly technical innovative industries, whether these communities can provide the critical affordance of broadband, is unclear. The better we understand rural communities and the industries they rely on, the more we can do to support those industries. However, library and information studies (LIS) researchers have a heritage of broadband research, and we offered several promising directions for further investigation into the relationship between broadband and AM in rural communities.

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