merits

Article

Ohio's 5G and Broadband Workforce: Assessing the Current Landscape Using Skillshed Analysis

Ryan Humeniuk *, Elham Erfanian and G. Jason Jolley

Voinovich School of Leadership and Public Service, Ohio University, Athens, OH 45701, USA
* Correspondence: rh480121@ohio.edu

Abstract: Ohio's 5G and broadband industry is rapidly changing. In this study, we assess the current skills and skills gaps of the state's workforce and the supply and demand of labor within the 5G and broadband industry. We use a skillshed analysis to determine declining occupations with easy and challenging transitions into 5G and broadband occupations. Based on the analysis, we determine where skills gaps exist and where additional resources are needed to prepare the state's workforce for the 5G and broadband industry.

Keywords: 5G and broadband; skillshed; Ohio; career transitions; workforce development

Citation: Humeniuk, R.; Erfanian, E.; Jolley, G.J. Ohio's 5G and Broadband Workforce: Assessing the Current Landscape Using Skillshed Analysis. *Merits* **2024**, *4*, 66–78. https://doi.org/10.3390/merits4010005

Academic Editor: Luis Miguel Ciravegna Fonseca

Received: 23 December 2023
Revised: 9 February 2024
Accepted: 20 February 2024
Published: 23 February 2024

1. Introduction

Advancements in fifth generation (5G) technology and broadband communications create novel opportunities in numerous sectors, especially with regard to workforce development. As modern society further shifts to become that of an 'information society', 5G and broadband investment, development, and use have been shown to increase income, employment, and business expansion, especially in rural areas [1–4]. It is important to note that the findings of these studies exist across multiple time periods; Whitacre et al. (2014) showed that increased broadband adoption increased median household income and business activity from 2008–2011 [1], while Isley and Low (2022) and Rupasingha et al. (2023) found that broadband adoption increased employment growth and employment rates in rural areas, both prior to and during the COVID-19 pandemic [2,3]. These results suggest that developments in rural broadband can be an important tool in fighting socioeconomic disadvantages that are all too common in rural communities. The aim of this study is to build a better understanding of the current skills and skills gaps with regard to 5G and broadband in Ohio's workforce and determine the investments that would be most effective in bridging those gaps. To accomplish this, we will use a skillshed analysis to compare the skills required by emerging occupations, derived from the expansion of 5G and broadband, to those required by declining occupations, which are the ones projected to see a reduction in employment in Ohio. Then, we will determine occupations that could have an easy transition from declining occupations into emerging occupations as a result of the 5G and broadband industry's expansion, as well as occupations that might have a more challenging transition. This study is important for three reasons: 1. 5G technology will generate many new jobs, income, added value, and output for both the US economy and Americans [5]. 2. 5G technology will lead to sustainable economic and community development, enhanced transportation networks, consumer savings, and societal interconnection in both rural and urban areas [6–8]. 3. There is currently a shortage of labor available to fill the needs of the 5G and broadband industry, hindering the rollout of broadband and other technology [9]. Few studies have assessed the gap between declining and emerging occupations, and none have assessed the 5G and broadband industry. This study seeks to fill this knowledge gap. For industries without standardized training practices, such as the 5G and broadband industry, understanding an occupation's necessary skills and identifying gaps in competency are important steps in developing the most relevant and efficient workforce education, especially programs designed to develop specific skills [10]. Additionally, several studies have noted the value in efficient resource management, or selecting, scheduling, and planning a workforce appropriate for the telecommunications industry, as well as adapting employees to their work rather than adapting work to a given workforce [11–14]. Many workers are unaware of the available careers related to 5G and broadband, while many educators are unaware of what skills are needed to train workers for the industry. This study is the first known skillshed analysis on the 5G and broadband industry. Thus, we aim to use this knowledge to inform policymakers, government officials, employers, and communities about workforce readiness to fill emerging occupations in the 5G and broadband industry. Although this study utilizes skills needed for each occupation according to US databases, the findings of this research play an important role for international 5G and broadband markets and related policies. While skills and knowledge needed for occupations are highly dependent on the current level of technology in each country, identifying necessary skills and occupational gaps between occupations, local wages, and employment projections are the major contributors to minimizing the costs associated with occupational transitions, regardless of the country.

Implementing 5G and broadband technology will increase the demand for labor to do so, thereby creating jobs and requiring workforce development. Significant resources have already been devoted to enhancing the rollout of broadband in the US. Roughly two-thirds of the Infrastructure Investment and Jobs Act's 64.4 billion dollars has been earmarked for the Broadband Equity, Access, and Development (BEAD) program [15,16]. Broadband services, which are typically divided into either fixed or mobile broadband, require a variety of skillsets to function properly. Some of the workers that are employed in broadband include construction workers, technicians, and network engineers and architects, in addition to those who service cell towers, which are only used in mobile broadband. As of January 2022, fixed and mobile broadband services employ over 550,000 workers in the US [16]. While unemployment rates among jobs related to broadband deployment suggest a labor shortage, other measures, such as employment and wage growth, do not. Findings by Congressional Research Services (2022) and the US Government Accountability Office (2022) are especially pertinent to rural areas, given that broadband workers tend to be sparse in these areas [15,16]. In addition, broadband workers cannot easily be brought into the rural communities. This fact corroborates the importance of training current residents. There has been an ongoing effort to increase opportunities and residents' knowledge in this area, in addition to training for 5G and broadband-related careers, as both apprenticeships and on-the-job training exist for such occupations.

1.1. Fifth Generation and Broadband

Discussions surrounding 5G technology have intensified in recent years as industrial shifts and changing consumer demand for technology have developed a need for more advanced telecommunications networks. While 5G builds on existing telecommunications networks, experts note that 5G technology has the potential to revolutionize the world by integrating multiple aspects of technology within everyday societal and economic functions [17]. Since first generation (1G) technology was introduced in the late 1970s [18,19], new generations have primarily focused on advancements in communication, such as transitioning from analog to digital technology and improving voice quality for calls. However, 5G marks a departure from these advancements in that it lays the groundwork for broader changes in how technology can be used.

Fifth generation makes use of advanced technology, both wired and wireless, to connect a variety of heterogeneous devices across networks made up of multiple layers [19,20]. This technology includes new radio (NR), multiple input multiple output (MIMO) antennas, and more [18]. Dangi et al. (2021) and Sohaib et al. (2023) note three key services brought about by 5G technology: (a) extreme mobile broadband (eMBB), (b) massive machine type communication (mMTC), and (c) ultra-reliable low-latency communication (URLLC). eMBB is primarily responsible for providing consumers with lightning-fast internet connections, allowing them to stream ultra-high-definition (UHD) videos and make use of augmented or virtual reality technologies [17,19,21]. For eMBB to effectively work, it must function in a variety of environments, including indoor settings, urban cores, and sparsely populated rural regions. mMTC primarily supports the internet of things (IoT) and encompasses the wide range of devices that must connect with one another in order for 5G technology to function effectively [22]. mMTC makes use of devices, such as sensors, that require a low volume of data to monitor processes that are not typically time sensitive. This allows for these processes to be completed in a cost-effective manner with low power consumption. Finally, URLLC involves processes in which instantaneous, low-latency communication is critical. Unlike mMTC, functions making use of URLLC are extremely time-sensitive. These include cases such as remote surgery procedures, vehicle to vehicle communication, and other industrial processes [23].

For the everyday consumer, advancements in broadband are perhaps the most significant changes brought about by 5G technology as telecommunications systems place a bigger emphasis on user experiences [24]. eMBB will allow for the high quality of service (QoS) and the large number of device connections that are necessary for 5G technology to function properly without using too much power, while also supporting broadcasts, such as mobile TV and live content, in addition to its support of the broadcast industry as a whole [25,26]. To fulfill the needs of eMBB, several solutions have been proposed. Some suggest the use of device-to-device (D2D) connections in order to reduce internet traffic volumes traveling through base stations. Others have noted the need for scheduling algorithms and technology beyond fiber-optic communication, such as millimeter wave wireless communication, which would allow for a wide range of coverage at a rapid pace [27,28]. Regardless of which solution or combination of solutions is used, significant upgrades in technology will be required to enhance existing mobile broadband networks.

1.2. Opportunities Related to 5G and Broadband

In addition to the enhancements in latency, data transmission, and video streaming that were mentioned previously, Liu et al. (2021) note that 5G will lead to changes in how robots can be used. Not only will these changes drive the use of robots in autonomous driving and remote surgery, but they will also allow them to better solve spatial problems, reducing costs associated with overcoming environmental barriers to robotic functions [29]. Furthermore, 5G will allow for improved delivery and transportation of goods, as well as enhancements in customer service brought about by developments in various industries that will ultimately contribute to a better quality of life for consumers. These developments include better healthcare, increased inclusion of those with disabilities, and enhanced interconnectedness between people, including between those impacted by the rural–urban divide [30]. Finally, 5G and broadband innovations provide opportunities for better food production, smart cities, and the integration of more sustainable technology within society [8,31]. In light of these opportunities, Wright (2023) notes that, due to the growing reliance on technology in institutions like education, everyone must have an equal opportunity to take advantage of such enhancements in broadband so that existing inequalities are not further exacerbated [32].

1.3. Fifth Generation and Broadband in Ohio

Between 2001 and 2021, there has been a significant decline in employment in the telecommunications sector, which includes 5G and broadband, both nationally and in Ohio [33]. However, the number of proprietors in the telecommunications industry has remained relatively stable. In 2021, just under 20,000 workers were employed in the telecommunications industry in Ohio, down from over 40,000 in 2001, while the number of proprietors has remained at roughly 4500. In light of anticipated investments in the sector, telecommunications employment is expected to increase. Workers hired by the telecommunications industry primarily consist of those responsible for installing equipment, many of whom have skills specific to the telecommunications industry, such as 'Telecommunications Equipment Installers and Repairers, Except Line Installers' and 'Telecommunications Line Installers and Repairers', both of which are among the most frequently employed occupations within the telecommunications industry. Some of the skills required by 'Telecommunications Equipment Installers and Repairers, Except Line Installers' include 'Repairing' and 'Troubleshooting', while 'Telecommunications Line Installers and Repairers' need to be skilled in 'Complex Problem Solving' and 'Operations Monitoring' [34,35]. Both occupations also require workers to be skilled in 'Critical Thinking', and they typically require workers to have at least a 'high school diploma or equivalent'.

In recent years, the state of Ohio has invested significant resources into the expansion of broadband and 5G technology. Governor Mike DeWine's office estimates that over 300,000 households, comprising almost 1,000,000 Ohioans, lack sufficient broadband access [36]. In response to these challenges, the state launched the Ohio Broadband Strategy in 2019, which seeks to assist those who are unserved or underserved by the state's existing broadband networks in accessing them. The state has also developed the BroadbandOhio Office, which, in addition to the resources provided by House Bill 2, will work to connect communities that lack broadband access. The office has also been tasked with community engagement and project management initiatives in order to expand access to online health and education resources in order to better connect residents with the modern-day economy.

The state has spearheaded various regional programs, in addition to programs developing Ohio's 5G and broadband workforce. These include Regional Digital Inclusion Alliances (RDIAs) across the state, which are supported by BroadbandOhio and the State Digital Equity Planning Grant Program [37]. RDIAs work to create cohesive regional plans and inclusion efforts for historically underserved populations. This program will work alongside other programs related to broadband equity and inclusion, such as the Ohio Residential Broadband Expansion Grant program, which was created using the state's $793 million in federal BEAD funding [38]. These programs will also work with community initiatives, such as the East Cleveland Connectivity Project, the Muskingum Valley Educational Service Center Telehealth Project, and the Riverside Connectivity Pilot [39–41]. Additionally, various programs meant to support employment in the 5G and broadband industry have been launched throughout the state, focused on providing residents with resources and opportunities focused on curriculum expansion, internship opportunities, and workforce training [9]. Engineering education programs can be difficult to develop due to the rapid pace at which technology changes. Therefore, such programs must ensure that students are able to adapt to new technological advancements post-graduation [42]. In spite of this, Ohio has invested significantly in programs, including the Telecommunications Industry Registered Apprenticeship Program (TIRAP), administered by the Wireless Infrastructure Association (WIA), which trains workers in 5G and broadband occupations; the TechCred program, which assists Ohio employers in funding workforce training for technology related occupations; and the Individual Microcredential Assistance Program (IMAP), which helps disadvantaged Ohioans to access occupational training resources free of cost. Effective utilization of educational investments such as these, in addition to investments in workforce training, can be an effective way to capitalize on existing investments in broadband and 5G technology while creating many job opportunities for Ohioans [9].

2. Materials and Methods

To better understand the nature of the workforce in relation to the growing 5G and broadband industry and the skill gap between those in declining occupations and emerging occupations in the growing 5G and broadband sector, we conducted a skillshed analysis. Skillshed analyses can be used to better understand the state of the workforce and the economic conditions of a given region by examining its skills, skills gaps, and the supply and demand of workers [43]. Skillshed analyses were first introduced by the University of Northern Iowa in 1998 in order to support the needs of economic development organizations in understanding the area's workforce [44,45]. Later, a standardized framework for conducting such analyses, developed by several midwestern communities, was detailed by Iowa Workforce Development in 2010. Iowa Workforce Development (2010) defines a skillshed as "the geographic area from which a region pulls its workforce and the skills, education, and experience that the workforce possesses" [43]. Skillsheds are different from laborsheds, which are the geographic areas from which an employer draws its employees [44].

To conduct a skillshed analysis, one must first define the geographic region that will be the skillshed. While skillsheds can be defined by natural features, such as rivers or political boundaries, they often extend beyond conventional boundaries to include the entire region that is centered around a central employment hub [44–46]. For our study, the skillshed we analyzed was the state of Ohio. Ohio offers ample opportunity for economic research. It is the 7th largest economy among US states and, on its own, the 21st largest economy in the world [47]. Additionally, Ohio is a national leader that has pioneered the implementation of 5G and broadband technology [48]. This provided an opportunity to assess how 5G and broadband will impact communities and economies across the state and, in a broader context, the nation. Finally, skillshed analyses are ideal for examining economies in transition or that have experienced negative economic events [46]. This is evidenced by the fact that, despite its size, Ohio's economy has long faced negative impacts related to declining regional industries, including mining and manufacturing [45]. The Legislative Service Commission (2020) notes in their report that not only is Ohio's unemployment rate higher than the national average, but its per capita income has been lower than the national average since 1970, and it has experienced a lower employment and GDP growth rate compared to the US as a whole [47].

After identifying a skillshed to analyze, we collected the data for the analysis. There were two categories of occupations that needed to be defined: 1. occupations that are in decline, 2. emerging occupations. This required skillshed-level data on occupations in the defined region to determine which occupations are in fact declining or emerging [46]. This could come from data sources such as the US Bureau of Labor Statistics (BLS) or local government agencies responsible for collecting employment data [49]. Ohio Department of Jobs and Family Services data were used to identify declining occupations in Ohio. To define emerging occupations, we consulted with subject matter experts from the 5G and broadband industry and the workforce. After the occupations were identified, the supply and demand for workers in the skillshed needed to be measured. Prior to this study, there had been a few published skillshed analyses that have been used to assess tobacco production in North Carolina [49], changes in Appalachian Ohio's coal economy [45], and the theoretical impacts of Amazon locating a second headquarters in the Columbus, Ohio, metropolitan statistical area [46]. However, to the best of our knowledge, there have yet to be any skillshed analyses assessing the 5G and broadband industry. Khalaf and Jolley (2020) note two main approaches to collecting such data: using surveys or using public databases [46]. Surveys can take the form of supply side surveys, which survey the workers in a skillshed, but they can also appear as demand side surveys, which survey the employers in a skillshed. While worker surveys examine their skills and occupational functions involved with their positions, employer surveys examine the skills and training that workers need. The results of both of these surveys are then evaluated to determine where gaps exist between the supply and demand for workers. However, survey-based approaches to data collection are notably expensive, time-consuming, and they are limited by workers' and employers' abilities to assess the labor market and the skills and functions that are needed to undertake a certain occupation [45]. Furthermore, there are, to our knowledge, no standardized procedures for conducting such surveys, meaning there is the potential for considerable variation between surveys. The other option for data collection, which we utilized in our study, is using publicly available employment data. This allows researchers to follow nationally standardized skill measurements while saving time and lowering costs. Our study drew skills and knowledge-related data from the Occupational Information Network (O*NET). O*NET classifies occupations based on the level of education they require and provides information on the level of competency in a given skill that is required by an occupation [45]. After an occupation's necessary skills are identified, dissimilarity measures between occupations are calculated using squared Euclidean distance. Finally, median hourly wages for the occupations analyzed must be incorporated into the model. This is typically done using BLS data or census data [49]. Wages are used to show the change in pay associated with transitioning from one career to another.

3. Results

The results of the skillshed analysis are displayed using two tables: one detailing occupations within the skillshed that require similar skills to other occupations and would likely have an easy transition to emerging 5G and broadband occupations, and other detailing occupations that require different skills from emerging 5G and broadband occupations and would likely have a difficult transition. Declining occupations and their median hourly wages within the skillshed are detailed along the vertical axis, while emerging 5G and broadband occupations and their wages are detailed along the horizontal axis. Each cell in the table contains two measures: (a) the change in hourly median wages associated with each occupational transition, which is denoted by the numerical value in the cell, and (b) the ease of transition, which is denoted by the cell's color. Cells follow a green–yellow–red linear color gradient, such that green denotes similar occupations that would likely allow for an easy transition, yellow denotes occupations that have a moderate transition, and red denotes dissimilar occupations that would likely have a challenging transition. Table 1 shows six declining occupations that would likely have an easy transition into nine emerging occupations, while Table 2 shows six declining occupations that would likely have a challenging transition into 10 emerging occupations.

Table 1. Skillshed applications with easy transitions.

		Construction Laborers	Electrical Power-Line Installers and Repairers	Electricians	Helpers—Installation, Maintenance, and Repair Workers	Operating Engineers and Other Construction Equipment Operators
		$22	$38	$29	$17	$29
Automotive Service Technicians and Mechanics	$19	$3	$19	$9	−$2	$9
Cement Masons and Concrete Finishers	$23	−$1	$15	$5	−$6	$5
Computer Numerically Controlled Tool Operators	$19	$3	$19	$9	−$2	$9
Engine and Other Machine Assemblers	$24	−$1	$14	$5	−$6	$5
Extruding, Forming, Pressing, and Compacting Machine Setters, Operators, and Tenders	$18	$4	$20	$11	$0	$11
Paper Goods Machine Setters, Operators, and Tenders	$18	$4	$20	$10	−$1	$10

For these tables, the darkest green cells show the easiest transitions while yellow cells show moderate transitions
transitions.

Table 2. Skillshed applications with challenging transitions.

		Computer Network Architects	Construction Managers	Electronics Engineers, Except Computer	First-Line Supervisors of Construction Trades and Extraction Workers	First-Line Supervisors of Mechanics Installers and Repairers	General and Operations Managers	Radio Frequency Identification Device	Radio, Cellular, and Tower Equipment Installers and Repairers	Software Quality Assurance Analysts	Telecommunications Engineering Specialists
		$49	$47	$48	$30	$31	$46	$47	$23	$49	$55
Bill and Account Collectors	$18	$32	$29	$30	$13	$13	$28	$29	$5	$32	$37
Cooks, Fast Food	$11	$39	$36	$37	$20	$20	$35	$36	$12	$39	$44
Helpers—Production Workers	$17	$32	$30	$30	$13	$14	$28	$29	$6	$32	$38
Postal Service Mail Carriers	$25	$24	$22	$22	$5	$6	$20	$21	−$2	$24	$30
Sewing Machine Operators	$14	$35	$33	$33	$16	$17	$31	$32	$9	$35	$41
Telemarketers	$14	$36	$34	$34	$17	$18	$32	$33	$10	$36	$41

For these tables, the darkest green cells show the easiest transitions while yellow cells show moderate transitions and the darkest red cells show the most difficult transitions.

Table 1 shows that there are 54 transitions that are considered easy, each of which can be used to identify the skills gap between occupations. The easiest transition in this table is ‘Cement Masons and Concrete Finishers’ to ‘Construction Laborers’, which leads to a $1 per hour decrease in median wages. These occupations both make use of ‘Coordination’, ‘Public Safety and Security’, and ‘Mechanical’ skills, as defined by O*NET, and they both require similar levels of training. The only skill gap between these occupations is in ‘Building and Construction’. While ‘Building and Construction’ is a skill of ‘medium’ importance for ‘Cement Masons and Concrete Finishers’, it is a skill of ‘high’ importance for ‘Construction Laborers’. This suggests that the skills gap between these occupations is relatively small. The most challenging transition in this table is ‘Cement Masons and Concrete Finishers’ to ‘Telecommunications Equipment Installers and Repairers, Except Line Installers’, which leads to a $6 per hour increase in median wages. The declining occupations that pay the least are ‘Extruding, Forming, Pressing, and Compacting Machine Setters, Operators, and Tenders’ and ‘Paper Goods Machine Setters, Operators, and Tenders’, with median wages of $18 per hour, while the one that pays the most is ‘Engine and Other Machine Assemblers’, with median wages of $24 per hour. The emerging occupation that pays the least is ‘Helpers—Installation, Maintenance, and Repair Workers’, with median wages of $17 per hour, while the one that pays the most is ‘Electrical Power-Line Installers and Repairers’, with median wages of $38 per hour. These results can then be used to assess the transitions with the greatest increase or decrease in wages. Transitioning from either ‘Extruding, Forming, Pressing, and Compacting Machine Setters, Operators, and Tenders’ or ‘Paper Goods Machine Setters, Operators, and Tenders’ to ‘Electrical Power-Line Installers and Repairers’ would lead to the greatest increase in median wages among the 42 total transitions that generate higher wages, increasing median wages by $20. Meanwhile, transitioning from ‘Engine and Other Machine Assemblers’ to ‘Helpers—Installation, Maintenance, and Repair Workers’ would lead to the greatest decrease in median wages among the nine transitions that generate lower wages, decreasing median wages by $6. Three transitions lead to no change in median wages: ‘Extruding, Forming, Pressing, and Compacting Machine Setters, Operators, and Tenders’ to ‘Helpers—Installation, Maintenance, and Repair Workers’, ‘Cement Masons and Concrete Finishers’ to ‘Paving, Surfacing, and Tamping Equipment Operators’, and ‘Cement Masons and Concrete Finishers’ to ‘Telecommunications Line Installers and Repairers’. For occupations with no change in wages, median wages may appear to differ between occupations due to rounding, despite there being little to no actual change in wages.

Table 2 shows that there are 60 transitions that, except for one, are considered to be the most challenging transitions between declining occupations and emerging 5G and broadband occupations. The easiest transition in this table is from ‘Helpers—Production Workers’ to ’Construction Managers’, which leads to a $30 per hour increase in median wages, while the most challenging transition is ‘Telemarketers’ to ‘Construction Managers’, which leads to a $34 per hour increase in median wages. While these jobs show some overlapping skill requirements, such as in ‘Speaking’ and ‘Persuasion’, they also have numerous gaps in skills, pertaining to business, resource, and system management. Typically, these skills are of ‘high’ to ‘very high’ importance for ‘Construction Managers’, but they tend to be of ‘very low’ importance for ‘Telemarketers’. This suggests that the skills gap between these occupations is relatively large. The declining occupation that pays the least is ‘Cooks, Fast Food’, with median wages of $11 per hour, while the declining occupation that pays the most is ‘Postal Service Mail Carriers’, with median wages of $25 per hour. The emerging occupation that pays the least is ‘Radio, Cellular, and Tower Equipment Installers and Repairers’, with median wages of $23 per hour, while the emerging occupation that pays the most is ‘Telecommunications Engineering Specialists’, with median wages of $55 per hour. These values show that, among the 59 transitions that lead to higher wages, the transition that generates the highest increase in median wages is the transition from ‘Cooks, Fast Food’ to ‘Telecommunications Engineering Specialists’, which increases median wages by $44 per hour. On the other hand, the only transition that leads to a decrease in median wages is the transition from 'Postal Service Mail Carriers' to 'Radio, Cellular, and Tower Equipment Installers and Repairers', which decreases median wages by $2 per hour. Every transition in Table 2 leads to a change in wages.

4. Discussion and Conclusions

The skillshed analysis conducted in our study has identified skills gaps between declining occupations and emerging occupations in the 5G and broadband industry, while showing how best to take advantage of the economic growth brought about by the emerging 5G and broadband industry. These results corroborate those noting the importance of adapting an industry's workforce to its work. Additionally, the skillshed analysis further identifies the numerous opportunities related to 5G and broadband development by showing that in most presented cases, transitioning from a declining occupation to an emerging one in the 5G and broadband sector leads to increased income, which, like the other advancements brought about by 5G and broadband, highlights the improved quality of life that can be brought about by the industry. To investigate the research problem and answer our research questions, we first identified occupational transitions that are easy, as well as those that are challenging and require more training, especially for dislocated workers. The analysis shows that occupations within construction sectors would have easy transitions into 5G and broadband occupations associated with construction (Table 1), while occupations within service sectors would have more challenging transitions into 5G and broadband occupations associated with construction or engineering (Table 2). This result was expected, given that construction jobs within different industries likely require similar skills, while jobs within service sectors likely require different skills than those within the construction and engineering sectors.

In addition to this, the skillshed analysis shows which workers are best suited for emerging occupations and which ones will require additional training. This is especially important when considering where there are reskilling or upskilling needs and where the new financial resources should be invested to support the 5G and broadband industry. Our skillshed analysis suggests that the largest skills gaps exist among occupations requiring engineering skills and some construction occupations requiring skills specific to developing 5G and broadband networks. Based on this information, leaders and policy makers will benefit from investing in state and federal programs not only focused on recent graduates, but also focused on training dislocated workers to work in such occupations to ensure the proper implementation of the infrastructure required for the effective functioning of 5G and broadband technology and the advancements it brings about. While the state has begun these investments under the state's 'Strengthening Ohio's Broadband and 5G Workforce' initiative by establishing relationships with universities, career centers, and other educational hubs around the state, experts note that lack of awareness is still a significant barrier to fulfilling the industry's demand for labor [9,48]. To resolve this issue, experts recommend outreach activities, expanding knowledge through workshops and training for teachers and students, and for curriculum to be developed in order to engage students in middle and high school rather than limiting program access to those at the post-secondary level [9].

Ohio's early investment into 5G and broadband technology provides significant insight and a roadmap for other regions, nationally and universally, as they begin to invest further in their technological infrastructure. Initial findings suggest that, along with developing programs to train workers for the needs of the 5G and broadband industry, leaders and policy makers should prioritize campaigns informing the public about such programs. Furthermore, investments made by the state in programs such as BroadbandOhio may help to inform other regions as to how they should implement such programs. However, further analysis is needed to determine whether or not the program has been effective in expanding 5G and broadband access across the state. While the insight provided by Ohio's investments may not apply to every region, it will be most informative to regions that share similar characteristics to the state, such as states in the Appalachian region, states that have been impacted by the decline in the coal economy, and midwestern states that have been impacted by the decline in their manufacturing industries. It is necessary for other states and countries that are in different stages of technology and workforce environments to adapt and regionalize what has been done in the state of Ohio.

There are limitations present in our skillshed analysis. Firstly, our study does not consider other currently emerging occupations outside of the 5G and broadband industry, nor does it evaluate occupations that may emerge in response to the growth of the 5G and broadband sector in Ohio. While there will be other occupations to emerge in the near future, occupations in the 5G and broadband industry will still play an important role in global economic development [17]. In addition, this study does not consider other competitive industries that compete in hiring 5G and broadband emerging occupations. Furthermore, because our study uses the most current and regional median wages to determine the change in hourly median wages that will occur, we cannot account for differences in final wage changes due to variation within the industry or changes in the market. Despite this, these results provide important insight on the general shifts in wages that will likely occur as a result of these transitions. We also cannot account for errors in the data. Finally, because our study focuses on the state of Ohio, our results cannot necessarily be generalized to states and regions outside of Ohio due to differences in industries and economic conditions. Nevertheless, our results shed light on the occupational transitions that are likely to occur as a result of the growth of the 5G and broadband industry. Based on the results of our study, as well as the limitations present, there is ample room for future research on the subject matter. Future studies might expand the analysis to incorporate emerging occupations not directly related to the 5G and broadband industry or industries competing with the 5G and broadband industry, in addition to evaluating transitions outside the state of Ohio to assess and compare the economic shifts that will occur across the US at the regional or national level.

Author Contributions: Conceptualization, G.J.J.; methodology, E.E.; software, E.E.; validation, E.E.; formal analysis, E.E.; investigation, E.E.; resources, E.E.; data curation, E.E.; writing—original draft preparation, R.H.; writing—review and editing, R.H., E.E. and G.J.J.; visualization, E.E.; supervision, E.E.; project administration, E.E.; funding acquisition, G.J.J. All authors have read and agreed to the published version of the manuscript.

Funding: A portion of the original data analysis used in this paper was supported by a subcontract award from the State of Ohio and Ohio State University originating from the US Dept. of Education PTE Federal Award #S425C210040. The APC was funded by Peter Balazac.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analyzed in this study. These data can be found here: https://www.onetonline.org/ (accesed on 10 November 2023) and https://ohi-olmi.com/Home/Projections/ProjectionsHome (accessed on 7 November 2023).

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Whitacre, B.; Gallardo, R.; Strover, S. Does rural broadband impact jobs and income? Evidence from spatial and first-differenced regressions. *Ann. Reg. Sci.* **2014**, *53*, 649–670. https://doi.org/10.1007/s00168-014-0637-x.
2. Isley, C.; Low, S.A. Broadband adoption and availability: Impacts on rural employment during COVID-19. *Telecommun. Policy* **2022**, *46*, 102310. https://doi.org/10.1016/j.telpol.2022.102310.
3. Rupasingha, A.; Pender, J.; Williams, R.; Goldstein, J.; Nair, D. Place-based subsidies and employment growth in rural America: Evidence from the broadband initiatives programme. *Pap. Reg. Sci.* **2023**, *102*, 677–708. https://doi.org/10.1111/pirs.12740.
4. Gayatri, G.; Jaya, I.G.N.M.; Rumata, V.M. The Indonesian digital workforce gaps in 2021–2025. *Sustainability* **2022**, *15*, 754. https://doi.org/10.3390/su15010754.
5. Prieger, J.E. *An Economic Analysis of 5G Wireless Deployment Impact on the U.S. and Local Economies*; ACT|The App Association: Washington, DC, USA, 2020.

6. Attaran, M. The impact of 5G on the evolution of intelligent automation and industry digitization. *J. Ambient. Intell. Hum. Comput.* **2023**, *14*, 5977–5993. https://doi.org/10.1007/s12652-020-02521-x.
7. Beltozar-Clemente, S.; Iparraguirre-Villanueva, O.; Pucuhuayla-Revatta, F.; Sierra-Liñan, F.; Zapata-Paulini, J.; Cabanillas-Carbonell, M. Contributions of the 5G network with respect to decent work and economic growth (sustainable development goal 8): A systematic review of the literature. *Sustainability* **2023**, *15*, 15776. https://doi.org/10.3390/su152215776.
8. Singh, S.; Rosak-Szyrocka, J.; Drotár, I.; Fernando, X. Oceania's 5G multi-tier fixed wireless access link's long-term resilience and feasibility analysis. *Future Internet* **2023**, *15*, 334. https://doi.org/10.3390/fi15100334.
9. Strengthening Ohio's Broadband and 5G Workforce. Governor's Office of Workforce Transformation. Available online: https://broadband.ohio.gov/wps/wcm/connect/gov/7bb60dea-a273-4622-9d0c-67e7201a8016/Strengthening-Ohios-Broadband-5G-Workforce-09072021.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=ROOTWORKSPACE.Z18_K9I401S01H7F40QBNJU3SO1F56-7bb60dea-a273-4622-9d0c-67e7201a8016-oEtqhRw (accessed on 14 December 2023).
10. Lin, C.-L.; Kuo, C.-L. Establishing competency development evaluation systems and talent cultivation strategies for the service industry using the hybrid MCDM approach. *Sustainability* **2022**, *14*, 12280. https://doi.org/10.3390/su141912280.
11. Ferreira, C. *Forecasting the Number of Technicians Required for the Data and Advanced Services of Telkom*; University of Pretoria: Pretoria, South Africa, 2011.
12. Mohamed, A.; Hagras, H.; Shakya, S.; Owusu, G. Tactical Resource Planner for Workforce Allocation in Telecommunications. In *Autonomous and Intelligent Systems*; Kamel, M., Karray, F., Hagras, H., Eds.; Lecture Notes in Computer Science; Springer: Berlin, Heidelberg, 2012; Volume 7326, pp. 87–94, ISBN 978-3-642-31367-7.
13. Kassem, S.; Hagras, H.; Owusu, G.; Shakya, S. A type2 fuzzy logic system for workforce management in the telecommunications domain. In Proceedings of the 2012 IEEE International Conference on Fuzzy Systems, Brisbane, Australia, 10–15 June 2012; IEEE: Brisbane, Australia; pp. 1–8.
14. Idrees, R.N.; Waqas, M.; Naqvi, I.H.; Imran, A.; Anjum, Z.-U.-Z. Strategic human resource management function and HR staffing: A case study of telecom sector. *Paradigms* **2019**, *12*, 153–160. https://doi.org/10.24312/paradigms120206.
15. Bridging the Digital Divide: Broadband Workforce Considerations for the 118th Congress. Available online: https://sgp.fas.org/crs/misc/IF12111.pdf (accessed on 14 December 2023).
16. Telecommunications Workforce: Additional Workers Will Be Needed to Deploy Broadband, but Concerns Exist about Availability. Available online: https://www.gao.gov/assets/gao-23-105626.pdf (accessed on 14 December 2023).
17. Navarro-Ortiz, J.; Romero-Diaz, P.; Sendra, S.; Ameigeiras, P.; Ramos-Munoz, J.J.; Lopez-Soler, J.M. A survey on 5G usage scenarios and traffic models. *IEEE Commun. Surv. Tutor.* **2020**, *22*, 905–929. https://doi.org/10.1109/COMST.2020.2971781.
18. Gupta, A.; Jha, R.K. A survey of 5G network: Architecture and emerging technologies. *IEEE Access* **2015**, *3*, 1206–1232. https://doi.org/10.1109/ACCESS.2015.2461602.
19. Dangi, R.; Lalwani, P.; Choudhary, G.; You, I.; Pau, G. Study and investigation on 5G technology: A systematic review. *Sensors* **2021**, *22*, 26. https://doi.org/10.3390/s22010026.
20. Chettri, L.; Bera, R. A comprehensive survey on internet of things (IoT) toward 5G wireless systems. *IEEE Internet Things J.* **2020**, *7*, 16–32. https://doi.org/10.1109/JIOT.2019.2948888.
21. Sohaib, R.M.; Onireti, O.; Sambo, Y.; Swash, R.; Ansari, S.; Imran, M.A. Intelligent resource management for eMBB and URLLC in 5G and beyond wireless networks. *IEEE Access* **2023**, *11*, 65205–65221. https://doi.org/10.1109/ACCESS.2023.3288698.
22. Kovalchukov, R.; Moltchanov, D.; Pirskanen, J.; Sae, J.; Numminen, J.; Koucheryavy, Y.; Valkama, M. DECT-2020 new radio: The next step toward 5G massive machine-type communications. *IEEE Commun. Mag.* **2022**, *60*, 58–64. https://doi.org/10.1109/MCOM.001.2100375.
23. Makeeva, E.; Kochetkova, I.; Alkanhel, R. Retrial queueing system for analyzing impact of priority ultra-reliable low-latency communication transmission on enhanced mobile broadband quality of service degradation in 5G networks. *Mathematics* **2023**, *11*, 3925. https://doi.org/10.3390/math11183925.
24. Tang, R.; Zhao, J.; Qu, H.; Zhang, Z. User-centric joint admission control and resource allocation for 5G D2D extreme mobile broadband: A sequential convex programming approach. *IEEE Commun. Lett.* **2017**, *21*, 1641–1644. https://doi.org/10.1109/LCOMM.2017.2681664.
25. Calabuig, J.; Monserrat, J.F.; Gomez-Barquero, D. 5th generation mobile networks: A new opportunity for the convergence of mobile broadband and broadcast services. *IEEE Commun. Mag.* **2015**, *53*, 198–205. https://doi.org/10.1109/MCOM.2015.7045409.
26. El-Saleh, A.A.; Alhammadi, A.; Shayea, I.; Alsharif, N.; Alzahrani, N.M.; Khalaf, O.I.; Aldhyani, T.H.H. measuring and assessing performance of mobile broadband networks and future 5G trends. *Sustainability* **2022**, *14*, 829. https://doi.org/10.3390/su14020829.
27. Li, X.; Yu, J.; Chang, G.-K. photonics-aided millimeter-wave technologies for extreme mobile broadband communications in 5G. *J. Light. Technol.* **2020**, *38*, 366–378. https://doi.org/10.1109/JLT.2019.2935137.
28. Mamane, A.; Fattah, M.; El Ghazi, M.; El Bekkali, M. 5G enhanced mobile broadband multi-criteria scheduler for dense urban scenario. *Telecommun. Syst.* **2022**, *80*, 33–43. https://doi.org/10.1007/s11235-022-00885-3.
29. Liu, Y.; Liu, X.; Gao, X.; Mu, X.; Zhou, X.; Dobre, O.A.; Poor, H.V. robotic communications for 5G and beyond: Challenges and research opportunities. *IEEE Commun. Mag.* **2021**, *59*, 92–98. https://doi.org/10.1109/MCOM.111.2001118.

30. Oinas-Kukkonen, H.; Karppinen, P.; Kekkonen, M. 5G and 6G broadband cellular network technologies as enablers of new avenues for behavioral influence with examples from reduced rural-urban digital divide. *Urban. Sci.* **2021**, *5*, 60. https://doi.org/10.3390/urbansci5030060.
31. Khelifi, A.; Aziz, O.; Farooq, M.S.; Abid, A.; Bukhari, F. social and economic contribution of 5G and blockchain with green computing: Taxonomy, challenges, and opportunities. *IEEE Access* **2021**, *9*, 69082–69099. https://doi.org/10.1109/ACCESS.2021.3075642.
32. Wright, R.G. The place of broadband within equal education opportunity. *Ind. Law. Rev. Arch.* **2023**, *56*, 519–529. https://doi.org/10.18060/27240.
33. Michael, N. IMPLAN Data Library. IMPLAN 2021. Available online: https://support.implan.com/hc/en-us/articles/360061667513-IMPLAN-Data-Library. (accessed on 14 December 2023).
34. *O*NET Telecommunications Equipment Installers and Repairers, except Line Installers*; O*NET OnLine: Williamson, GA, USA, 2023.
35. *O*NET Telecommunications Line Installers and Repairers*; O*NET OnLine: Williamson, GA, USA, 2023.
36. Office of the Governor Broadband (Expansion of High-Speed Internet). Available online: https://governor.ohio.gov/priorities/ohio+broadband/broadbandohio (accessed on 14 December 2023).
37. State Digital Equity Planning Grant. Available online: https://broadband.ohio.gov/grant-opportunities/state-digital-equity-grant/state-digital-equity-planning-grant (accessed on 14 December 2023).
38. Ohio BEAD Challenge Process and Grant Program. Available online: https://broadband.ohio.gov/explore-broadband/bead-challenge-process (accessed on 14 December 2023).
39. East Cleveland Connectivity Project. Available online: https://broadband.ohio.gov/explore-broadband/broadbandohios-projects/east-cleveland-connectivity-project (accessed on 14 December 2023).
40. Muskingum Valley Educational Service Center Telehealth Project. Available online: https://broadband.ohio.gov/explore-broadband/broadbandohios-projects/muskingum-valley-educational-service-center-telehealth-project (accessed on 14 December 2023).
41. Riverside Connectivity Pilot. Available online: https://broadband.ohio.gov/explore-broadband/broadbandohios-projects/riverside-connectivity-pilot (accessed on 14 December 2023).
42. Hazrat, M.A.; Hassan, N.M.S.; Chowdhury, A.A.; Rasul, M.G.; Taylor, B.A. Developing a skilled workforce for future industry demand: The potential of digital twin-based teaching and learning practices in engineering education. *Sustainability* **2023**, *15*, 16433. https://doi.org/10.3390/su152316433.
43. Skillshed Analysis: Guide to Identifying Your Workforce Skills. Available online: https://www.yumpu.com/en/document/read/44204501/skillshed-analysis-guide-to-identifying-your-workforce-skills (accessed on 15 December 2023).
44. Scott, H.; Kotlyar, I. *A Review of Skillshed Analysis Practices and Outcomes—Results of a Study Carried Out with Funding from the Social Sciences and Humanities Research Council of Canada*; University of Ontario Institute of Technology: Oshawa, ON, Canada, 2013. https://doi.org/10.13140/RG.2.2.14362.85449.
45. Jolley, G.J.; Khalaf, C.; Michaud, G.; Sandler, A.M. The economic, fiscal, and workforce impacts of coal-fired power plant closures in Appalachian Ohio. *Reg. Sci. Policy Pract.* **2019**, *11*, 403–422. https://doi.org/10.1111/rsp3.12191.
46. Khalaf, C.; Jolley, J. Skillshed analysis as a tool to inform workforce training programs: The case of Amazon HQ2. *J. Econ. Dev. High. Educ.* **2020**, *3*, 1-5.
47. Ohio Facts: 2020 Edition. Available online: https://www.lsc.ohio.gov/assets/organizations/legislative-service-commission/files/2020-ohio-facts.pdf (accessed on 15 December 2023).
48. Husted Announces Grant Programs to Support Ohio's Broadband & 5G Workforce. Available online: https://broadband.ohio.gov/news-and-events/all-news/2023-0124-husted-announces-grant-programs-to-support-ohios-broadband-5g-workforce (accessed on 15 December 2023).
49. Khalaf, C.; Michaud, G.; Jolley, J. How to assess the transferability of worker skills: A hybrid clustering approach. *J. Reg. Anal. Policy* **2021**, *51*, 67–78. https://doi.org/10.13140/RG.2.2.34691.07204.