Ten Years of Fiber Optic and Smart Grid Infrastructure in Hamilton County, Tennessee

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Table of Contents

List of Tables

List of Figures

List of Case Studies

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EXECUTIVE SUMMARY

This study computes the realized economic value of fiber optic infrastructure in Hamilton County and the city of Chattanooga, over a (roughly) 10-year period from 2011 to March 2020. Our estimates show that the economic value of the fiber optic infrastructure, i.e. high-speed broadband and the smart grid, minimally exceeds $2.69 billion and 9,516 jobs over the study period. The value exceeds the costs of the project by over $2.20 billion, or by a factor of 4.42. Roughly 40 percent of all jobs created in Hamilton County in the study period can be attributed to the fiber infrastructure. As seen in Table 1, approximately 52 percent of the value of the infrastructure is manifested in local economic development, i.e. over $1.4 billion in new investments, startup funding, real estate development and payments-in-lieu of taxes (PILOT). The smart grid has generated 28 percent of the estimated value in just over eight years from 2012. The remainder of calculated value stems from business efficiencies, household and community effects. Each county resident is estimated to have benefited by about $646 per year due to the incremental value generated by the fiber optic infrastructure.

Table 1. Summary of Estimates of Value (2011-2020)

Category	Source	$ Millions	% of total
Economic Development	Business Investments	$962.8	35.7%
	Startup Funding	$244.4	9.1%
	Real Estate Development	$141.6	5.3%
	PILOT	$59.9	2.2%
Smart Grid	Smart Grid	$750.2	27.8%
Business Effects	Productivity Gains	$74.31	2.8%
Household Effects	Consumer Surplus	$128.8	4.8%
	Residential Bill Savings	$144.9	5.4%
Community Effects	Healthcare	$18.17	0.7%
	Telecommuting	$90.62	3.4%
	Education	$29.83	1.1%
	Publicity	$47.49	1.8%
	Other	$3.65	0.1%
Total Value		$2,696.73	100.0%
Total Jobs		9,516	
Incremental Value-to-Cost ratio		4.42x	

These estimates exceed the projections made at the time the infrastructure was planned (Lobo, Ghosh and Novobilski, 2006). They also exceed a linear extrapolation of estimates based on the period 2011-2015 (Lobo, 2015). It is likely that as more granular local usage data becomes available, new and improved measures of value will add to the estimates reported in this study.

CHAPTER 1. INTRODUCTION

Fiber optic infrastructure was brought to Chattanooga and Hamilton County, TN in 2009 by EPB ("Our History") at a cost of $396.1 million (Lobo, 2011). The infrastructure has resulted in high speed broadband to homes and businesses, and a smart electric grid in the EPB footprint. In September 2010, EPB made available residential symmetrical internet connection speeds of up to one gigabit per second - the fastest Internet in the western hemisphere at the time and the "gig city" moniker began to be applied to Chattanooga. In 2015, EPB made 10 gigabit internet service available to every home and business in its 600 square mile service area.

In a five-year lookback at the realized value of fiber optic infrastructure in Hamilton County, Lobo (2015) estimated that the infrastructure had "*generated incremental economic and social benefits ranging from $865.3 million to $1.3 billion while additionally creating between 2,800 and 5,200 new jobs*" over the period 2011-2015. About 75 percent of the recorded gains to the County were driven by new investments, business efficiencies and from the many benefits of the smart grid. The study concluded that "*…the true economic value of the fiber infrastructure is much greater than the cost of installing and maintaining the infrastructure. As measurement methods improve, new pockets of value will likely be discovered which will add to the values reported in this study*." [p.4]

This study seeks to extend the analysis in Lobo (2015) in analyzing the realized economic value of fiber optic infrastructure in Hamilton County and the city of Chattanooga, over a (roughly) 10-year period from 2011 to March 2020. This analysis takes an analytical look at the broad research question: What have been the incremental effects of high-speed broadband and the smart grid in Hamilton County TN? The question draws us to bigger issues, such as "how do we measure the value of the internet?", and "how do we value transactions that are not monetized?" Hal Varian of Google concluded in 2013, "*It is now possible for everyone on the planet to have access to all the information humans have ever produced. The barriers to this utopian dream are not technological, but legal and economic. When we manage to solve these problems, we will be able to unlock vast pools of human potential that have hitherto been inaccessible. In the future this will be viewed as a turning point in human history….*"

Traditionally, the economic effects of infrastructure projects such as internet access have been measured either with an input-output model, or via analytical techniques. Either approach must distil the incremental effect of fiber-delivered high-speed broadband and the smart grid relative to a world without those technologies or with different technologies. Greenstein and McDevitt (2011) argue that early studies of the value of broadband were overestimated because the "incremental" element of the new service was not considered. In distilling the incremental effects of high-speed broadband, studies such as this one must adjust for the counterfactual case of having an alternative infrastructure in place, i.e. pre-broadband or first-generation broadband as opposed to high-speed broadband, and a traditional instead of a smart electric grid. Measured effects must also be careful to separate confounding factors from those that are directly attributable to the technology/infrastructure being studied.

As people get used to accessing the internet at faster and faster speeds, they take that infrastructure for granted. It is often hard to place in perspective the improvements of high-speed broadband relative to slower speeds and dated technologies. Moreover, advancements in broadband technology spur advancements in applications, hardware and software, making it difficult with the passage of time to isolate the effects of the infrastructure. The analysis is made more challenging by a lack of technology usage/adoption data at the local level, and sometimes even at the national level. On the other hand, studies such as this one focused on a particular community, help inform future studies on research questions worth answering. This study has benefited from numerous conversations with individuals in diverse lines of work, several of which are shown as case studies in this report, about how they use bandwidth and what they can do with enhanced bandwidth that they could not previously.

The scientific literature on the effects of high-speed broadband on economic outcomes has evolved substantially in the past decade. Our approach has been to review the academic/scientific literature for work relevant to this study and then to trace the local effects with local data and case studies. While good faith efforts have been made to be as systematic as possible in capturing the effects of the fiber infrastructure, such an endeavor has an element of *ad hoc-ism*. This is because no holistic theory exists to capture the impact of broadband access to the internet. Consequently, the empiricist must approach the problem in a reasonable but practical way. People do not generally consider counterfactuals when assigning benefits and costs to "free" services – a requirement of this study. This is especially true when a service such as broadband gets to be widely used and ubiquitous availability is expected. Consequently, our approach has been to examine areas indicated in Lobo (2011, 2015) and references therein, that are most likely to be impacted by the fiber infrastructure, such as healthcare, education and business productivity, and to develop metrics appropriate for those sectors/areas with available data.

The development of metrics is challenging. How do you measure the value of an evolving entrepreneurial ecosystem? Are firms attracted to an area because of particular features of the digital infrastructure? How can we attribute investments and jobs to particular features of a location when such answers are not elicited from relocating firms? How do you measure the satisfaction of instantly learning something on the internet? Productivity gains are particularly hard to measure. What is the dollar value of a teacher who has more time to engage with students because she doesn't have to spend an excessive amount of time uploading and downloading files and dealing with a slow internet connection? How does one value continuity in education when a pandemic breaks out?

In some cases, we have identified benefits in the form of cost savings or time savings. We attribute effects to the fiber infrastructure by adjusting raw estimates for the adoption (or take) rate of fiber services in the EPB footprint. We also apply the notion of consumer surplus to capture non-monetary benefits of convenience and reliable connectivity that comes from high-speed internet access. Recent work by Brynjolfsson et al. (2018) points to massive value provided by the internet to consumers. They measure the annual consumer surplus in 2017 of various, typical internet activities and conclude that the average person gains a value equivalent to approximately $32,000 per year from the free services on the internet. That translates to approximately $7.9 trillion in extra value when applied to all U.S. adults. Further, Hooton (2019) suggests that 25 percent of this consumer surplus can be attributed to non-commercial, personal use.

COVID-19, the new coronavirus pandemic that has gripped the world in 2020, has spotlighted the value of digital communication infrastructure. In a compilation of smart solutions to combat the coronavirus, the Washington Post (April 30, 2020) reports on the value of broadband infrastructure not merely for work-from-home (WFH) solutions, virtual schooling and Netflix parties, but for such diverse uses as prison inmate communication, combating mental health problems stemming from isolation and silence, providing telehealth solutions, especially to the 25 percent of Americans who do not have a primary care doctor, "hospital-at-home" programs, voter engagement and participation, home testing and contact tracing measures.

Since the onset of the pandemic, the average daily broadband usage in the United States has gone up markedly. According to Statista, in the week from March 11 to March 18, 2020, the average daily broadband data usage per user in the United States was 6.3 GB during office hours, an increase of 41.4 percent compared to January, even as the distinction between peak and off-peak times blurred. This increase was most likely due to more people working from home and nation-wide stay-at-home restrictions. In an article dated March 25, Beech (2020) reported that total internet hits had climbed by between 50 percent and 70 percent, and that streaming had also jumped by at least 12 percent in the first couple of weeks of the pandemic lockdown. The increased consumption of digital content was being observed worldwide. with the most broadband-hungry applications being online entertainment, especially those in high-definition (e.g. 4K movies and TV). Fishman (2020) notes, "*To the degree that any institution is keeping American society knitted together during this [coronavirus] crisis, it's the internet….By the end of April, network traffic during the workweek was up 25 percent from typical Monday-to-Friday periods in January and February.*"

The shift in work norms and the disruption of schooling has drawn attention to "last mile" connectivity to people's homes in the suburbs rather than in the downtown skyscrapers and office parks. Importantly, as the U.S. begins the process of reopening the economy, states are strategically reimagining the economy as they prepare for emerging trends that will shape life in the wake of the pandemic. For instance, working from home and teleconferencing, telehealth, voting by mail or online, digitally shopping for groceries, distance learning, and so on. All of these developments will require robust, reliable and speedy internet connectivity (Clark, 2020). Real time data and analysis will drive all forms of economic measurement and prediction models. People, businesses, and devices have all become data factories that are pumping out incredible amounts of information to the web each day. By 2025, it is estimated that 463 exabytes[1] of data will be created each day globally. For every second of the day, there is 88,555 GB of Internet traffic. It is clear that high-speed broadband is a minimum requirement to harness this data. It is essential, not a luxury.

In the analysis to follow, by "high-speed broadband" we mean 100+ Mbps of symmetric service. The FCC's current definition of broadband is minimally 25 Mbps download and 3 Mbps upload speed. The effects of high-speed broadband will be analyzed broadly in five categories: economic development, smart grid, business effects, household effects, and community effects. This is one of many classifications possible. The categories are not mutually exclusive but are merely an attempt at organizing the analysis. In particular, household effects are those that can be attributed to individual households. Community effects, by contrast, accrue to the community-at-large but cannot be directly linked to individual households. Business effects, however, overlap community

[1] An exabyte is equivalent to one billion gigabytes (GB).

and household effects since benefits to local businesses benefit the local economic landscape. Importantly, smart grid effects strongly overlap community effects because the utility (EPB) is city-owned. Additionally, the benefits from reducing the costs of major weather events due to the smart grid accrue mostly to businesses and households in terms of a reduction in lost productivity and economic activity. However, we include these benefits in the "Smart Grid Effects" section of the paper because they emanate from the smart grid infrastructure. Note especially, that in some cases (e.g. healthcare, education, civic services) local data is difficult to get or unavailable. As a consequence, the measured Community Effects may seem small in relative terms.

In this study, we mostly refer to the Hamilton County geographic unit for consistency with previous studies. Occasionally, due to data constraints we refer interchangeably to Chattanooga and the Chattanooga MSA because of the substantial overlap in these geographical units with the EPB (fiber optic) footprint as seen in **Fig 1.1** below.[2]

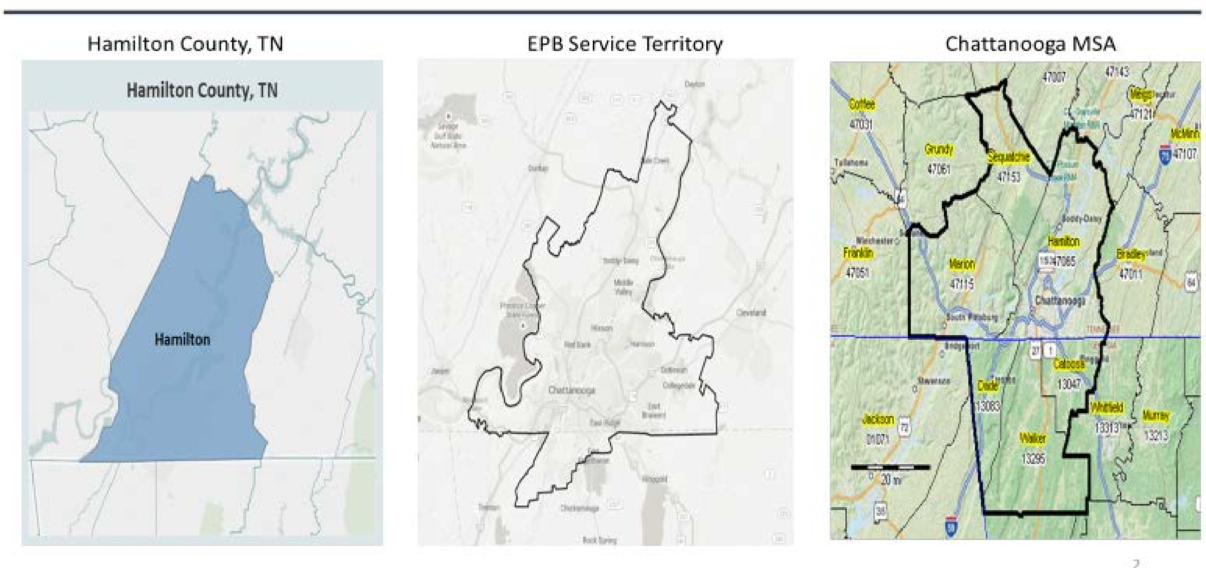

Fig. 1.1 Maps relevant to this study

[2] The EPB footprint covers about 78 percent of Hamilton County, and 100 percent of Chattanooga.

CHAPTER 2. HAMILTON COUNTY, TN

Hamilton County is the fourth largest of 95 counties in the southeastern U.S. state of Tennessee. As of July 2019, the County had a population of 367,804, which has grown 9.3 percent over the 2010-2019 period, above the national average of 6.3 percent. The County GDP was $26.3 billion in 2018 with median household income of $53,035 placing the County in the middle quintile of the national household income distribution.

2.1 Demographic Profile

Table 2.1 shows that the population in Hamilton County is 71 percent white, 18 percent black, and 6 percent Hispanic. The median age is 39.6 years with a gender breakdown that is roughly 48 percent male, and 52 percent female. The population is less diverse compared to the rest of the nation, but more so than the rest of the state. Eighty-nine percent of the population has a high school education or better, while 31.4 percent have a bachelor's degree or higher, in line with the national average.

Table 2.1 Hamilton County Demographic Profile

	Hamilton County	Tennessee	USA
Population estimates (July 1, 2019)	367,804	6,829,174	308,758,105
Population, percent change (2010-2019)	9.3%	7.6%	6.3%
Population per square mile, 2010	620.3	153.9	87.4
Population white alone	71.0%	78.5%	60.4%
Language other than English spoken at home, percent of persons age 5 years+, 2014-2018	6.5%	7.1%	21.5%
Persons 65 years and over	17.6%	16.4%	16.0%
Persons under 18 years	20.8%	22.2%	22.4%
High school graduate or higher, percent of persons age 25+, 2014-2018	89.2%	87.0%	87.7%
Bachelor's degree or higher, percent of persons age 25+, 2014-2018	31.2%	26.6%	31.5%
Median gross monthly rent (2014-2018)	$840	$841	$1,023
Households (2014-2018)	140,890	2,567,061	119,730,128
Persons per household (2014-2018)	2.46	2.53	2.63
Households with a computer	86.0%	85.2%	88.8%
Households with broadband internet subscription, (2014-2018)	77.9%	75.4%	80.4%
Persons without health insurance, under age 65	11.9%	12.0%	10.0%
Median household income (in 2018 dollars), 2014-2018	$53,035	$50.972	$63,179
Median hourly wage rate	$17.03*	$17.26	$19.14
Persons in poverty	13.0%	15.3%	11.8%
Median value of owner-occupied housing units, 2014-2018	$171,400	$158,600	$204,900
Mean travel time to work (minutes), workers age 16+, 2014-2018	21.7	25.0	26.6
Source: U.S. Census: American Community Survey 2018: 5-year Estimates; * Chattanooga MSA.			

2.2 Commercial Profile

Data from the Bureau of Labor Statistics (BLS) in **Table 2.2** shows that there were 30,007 firms and 9,032 establishments in the County. Seventy-three percent of these firms are small businesses with fewer than 20 employees, while roughly 16 percent have 100+ employees, and 12 percent have 500+ employees. The larger firms (100+ employees) support roughly 70 percent of County employment. With a labor force of 187,743, the employment rate was 96.5 percent in March 2020, *prior to the effects of COVID-19.*

Table 2.2 Hamilton County Business Profile			
	Hamilton County	**Tennessee**	**USA**
All firms, 2012	30,007	550,453	27,626,360
Establishments[3]	9,032	137,918	7,860,674
Civilian labor force (March 2020)	187,743	3,362,841	162,913,000
Total employment (March 2020)	181,063	3,160,400	151,572,000
Total annual payroll, 2017 ($000)	$8,169,558	$120,113,689	$6,725,346,754
GDP (2018)	$26.3 billion	$364.1 billion	$18.6 trillion
Source: U.S. Census and Bureau of Labor Statistics. GDP is from the Bureau of Economic Analysis.			

According to the 2017 U.S. Census' On The Map program, roughly 74 percent of workers live and work in the County; 26 percent work outside the County. However, because the County has more jobs than workers, roughly 45 percent of County labor is drawn from Bradley (TN), the north Georgia counties of Catoosa and Walker, and from neighboring counties in Tennessee, Georgia and Alabama. The County has a net job inflow of approximately 51,200. Of these, 16 percent are for goods-producing jobs, 29 percent are for trade/transportation/utilities, and 54 percent are for all other service producing jobs. BLS data reveals that the most common job groups in Hamilton County are Office & Administrative Support, Sales & Related, and Management occupations.

The industrial and occupational structure of the County is shown in **Table 2.3**. Over 75 percent of employment in the County is attributable to educational and health services, manufacturing, retail trade, accommodation and food services, professional and business services, and finance and insurance services. The County has a larger fraction of employment in manufacturing, finance and transportation compared to national averages, and a relatively smaller fraction of employment in public administration and the information sectors.

We also identify in Table 2.3, those sectors where at least 50 percent of jobs can mostly be done remotely. Dingel and Neiman (June 19, 2020), in an ongoing study of work-from-home (WFH) jobs inspired by the COVID-19 pandemic, find that 37 percent of U.S. jobs, accounting for 46 percent of overall wages, can be performed almost entirely from home, with significant variation across cities and industries. For the Chattanooga MSA, they find that 32 percent of all jobs can be

[3] The U.S. Bureau of Labor Statistics (BLS) defines an establishment as an economic unit that produces goods or services, usually at a single physical location, and is engaged in one or predominantly one activity. A firm is a legal business, either corporate or otherwise, which consists of one or more establishments.

done from home.[4] The sectors most adaptable to WFH are marked with an asterisk in the table. Later, we use these sectors as a proxy for high-tech industries in the County.

Table 2.3 Hamilton County Employment by Industry & Occupation (2018)

	Hamilton County	Tennessee	USA
Industry	% of Total		
Educational services, and health care and social assistance*	22.6%	22.6%	23.1%
Manufacturing	12.9%	13.1%	10.2%
Retail trade	11.8%	12.0%	11.3%
Arts, entertainment, and recreation, and accommodation and food services	9.9%	9.6%	9.7%
Professional, scientific, and management, and administrative and waste management services*	9.9%	9.7%	11.4%
Finance and insurance, and real estate and rental and leasing*	8.5%	5.8%	6.6%
Transportation and warehousing, and utilities	6.8%	6.5%	5.2%
Construction	5.6%	6.4%	6.5%
Other services, except public administration	5.2%	4.8%	4.9%
Public administration	2.9%	4.2%	4.6%
Wholesale trade	2.3%	2.6%	2.6%
Information*	1.4%	1.8%	2.1%
Agriculture, forestry, fishing and hunting, and mining	0.3%	1.0%	1.8%
Occupations	% of Total		
Management, business, science, and arts occupations*	37.7%	34.7%	37.9%
Service occupations*	16.3%	17.0%	17.9%
Sales and office occupations*	24.2%	22.6%	22.1%
Natural resources, construction, and maintenance occupations	7.3%	8.8%	8.9%
Production, transportation, and material moving occupations	14.5%	16.9%	13.3%

Source: Census; * are industries and occupations where at least 50% of all jobs can be done from home based on Tables 1 and 3 from Dingel and Neiman (June 19, 2020).

The primary city in the County is Chattanooga, with a population of about 180,557; the Metropolitan Statistical Area (MSA) has a population of 570,000. When it is not being called the "scenic" city, Chattanooga is called the "gig" city because it was the first city in the western hemisphere to boast gigabit speed broadband in 2009. Data from the Chattanooga Area Chamber of Commerce shows that the biggest employers in the City are Erlanger Health System, Blue Cross Blue Shield of Tennessee, Hamilton County Schools, Tennessee Valley Authority and the Unum Group. More recently, Chattanooga has come to be referred to as "freight alley" or the "Silicon Valley of Trucking" due to the heavy concentration of transportation and logistics firms in the area.

[4] By way of comparison, San Jose-Sunnyvale-Santa Clara, CA was the top-rated metropolitan area with 51 percent of jobs that could be done from home. Mongey, Pilossoph and Weinberg (2020) find that individuals who cannot work at home are more likely to be lower-income, lack a college degree, rent their dwellings, be non-white, and lack employer-provided health insurance.

Case Study 1: Inc. magazine names 10 Chattanooga firms as fastest growing

A new list of America's fastest growing businesses by Inc. magazine identifies 10 Chattanooga companies among the list of 5,000 rapidly growing companies started in recent years. Eight of the 10 local companies on the Inc. 5000 list are in the high-tech, bandwidth-hungry logistics and transportation industry and another, Reliance Partners, is an insurance broker that serves the trucking industry. The 2020 Inc. 5000 achieved an incredible three-year median growth rate of 165 percent (Flessner, 2020a).

"*This city has more people connected to logistics per capita than any other city in America, so it was only natural that Chattanooga become the Silicon Valley of Trucking*," said Craig Fuller, founder of FreightWaves, in a recent podcast.

The Chattanooga firms named were *Trident Transport, Avenger Logistics, LYNC Logistics, Reliance Partners, Taimen Transport, FitzMark, max trans logistics, Conversant Group, Steam Logistics*, and *AHS Consultants*.

2.3 Broadband Profile

FCC Form 477 data shows that approximately most of Hamilton County residents have access to gigabit speed internet in 2019.[5] According to BroadbandNow.com, there are 21 internet service providers in Chattanooga as of April 2020. Of these providers, 6 offer residential service (EPB Fiber Optics, AT&T, Xfinity by Comcast, Earthlink, Viasat, and HughesNet). EPB is the only provider of fiber services to homes and businesses in Hamilton County and Chattanooga. EPB and Comcast are the only providers of gig-speed connectivity in the County. In 2015, EPB made the "*world's first 10 gigabit (10 Gig) internet service…available for access by every home and business in a 600 square mile area*." The average download speed in Chattanooga is 75.43 Mbps. This is 5.7 percent faster than the average in Tennessee and 13.4 percent faster than the national average.

While access data shows deep penetration in Hamilton County, data from the Census Bureau shows that broadband (defined as 25 Mbps download and 3 Mbps upload) subscriptions (adoption) for fixed wireline broadband have averaged about 80 percent in the period from 2013 to 2018. A digital divide index (DDI) was created for Hamilton County by the Purdue Center for Regional Development (See **Fig 2.1**).[6] The DDI shows that when compared to census tracts in Tennessee, Hamilton County shows relatively no digital divide (DDI=0.0); when compared to all census tracts in the U.S., the DDI is 12.38, still low but indicative of the need for efforts to focus on digital

[5] Noting the fact that fewer than 25 percent of Tennesseans had high-speed broadband connections, the Tennessee Department of Economic and Community Development concluded that "*Having access to broadband services is quickly becoming the most important differentiating infrastructure of our time. Education, healthcare, business operations and innovation, workforce training and e-government applications all rely upon advanced broadband networks.*" (Flessner, 2016)

[6] Special thanks to Roberto Gallardo, Ph.D., Director of the Purdue Center for Regional Development, for the DDI scorecard. The digital divide index score (DDI) ranges between 0 and 100, where a lower score indicates a lower divide. The infrastructure adoption score and the socioeconomic score contribute to the overall DDI.

literacy and exposing residents to the benefits of the technology rather than upgrading the infrastructure.

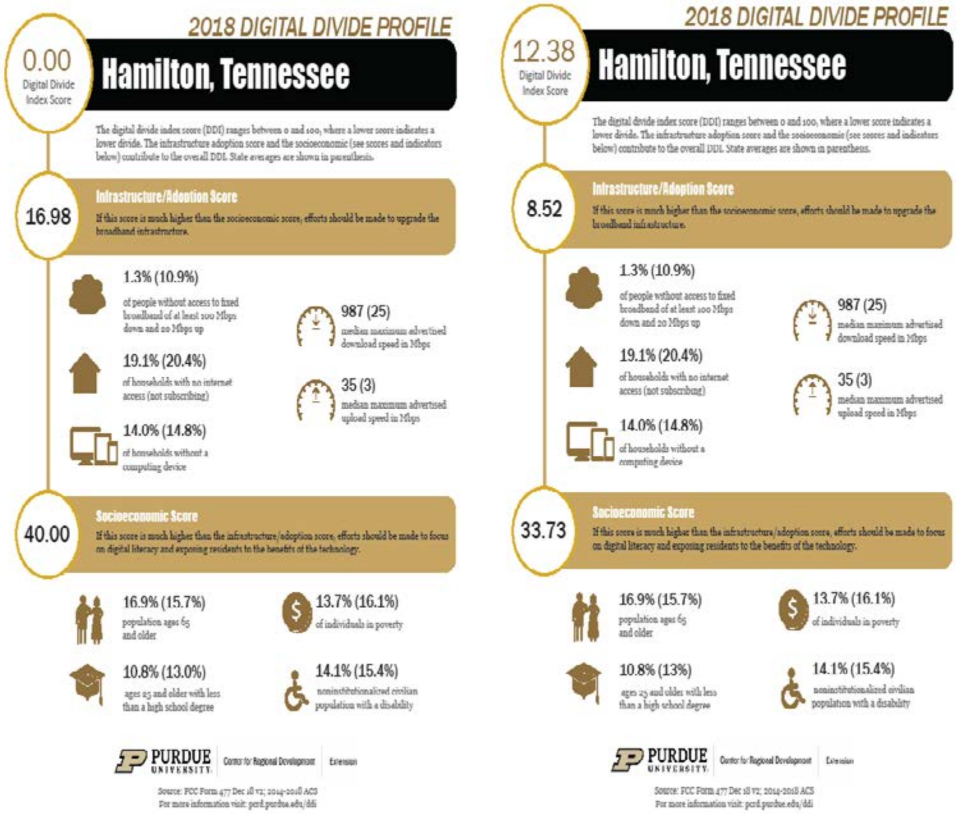

Fig. 2.1 Digital Divide Index for Hamilton County, TN

By April 2020, roughly 58 percent of the Chattanooga residential market and 30 percent of the commercial market subscribed to EPB fiber-delivered broadband service. **Fig. 2.2** shows high-speed fiber broadband take rates (or adoption rates) for residential and commercial EPB customers. The chart includes data-only plans as well as bundled plans. The chart also includes gig-speed customers. While the uptrend in take rates is obvious, we note that commercial take rates are more gradual than residential take rates. As of June 2020, over 100,000 of residential households in the EPB footprint were fiber customers.

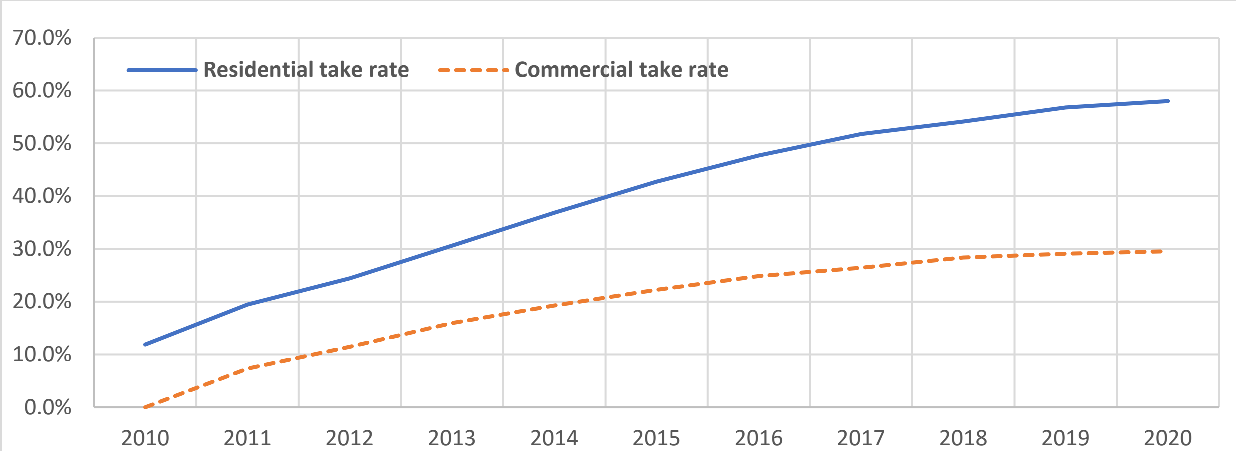

Fig. 2.2 EPB - Fiber Optic Data Take Rates 2010-2020

Fig. 2.3 shows the rapid adoption of gigabit broadband from less than 0.5 percent to over 13.5 percent of all residential customers over the past five years.

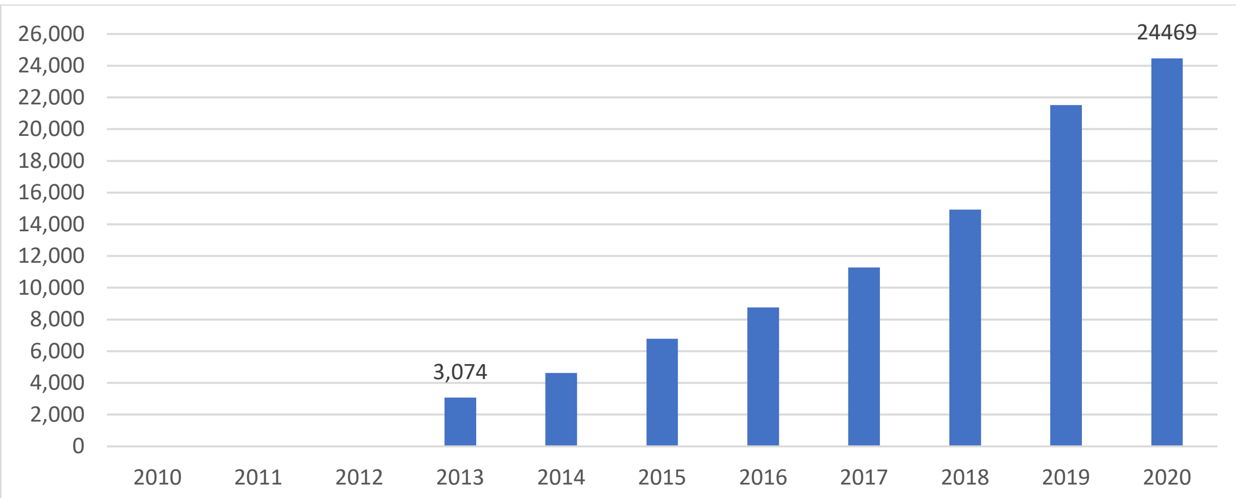

Fig. 2.3 EPB - Residential fiber gigabit subscriptions

2.4 COVID-19 Effects

In the wake of the COVID-19 pandemic, BroadbandNow found Chattanooga's broadband connections have remained relatively consistent even though usage has jumped as telework and virtual communications have skyrocketed and people are encouraged to stay at home. EPB's VP of technical operations said that "*One of the benefits for customers who use EPB's 100% fiber optic network is that it provides ample capacity as their needs increase and shift*." (Flessner, 2020b)

CHAPTER 3. ECONOMIC DEVELOPMENT

Local economic development is importantly affected by infrastructure investments such as the fiber optic infrastructure in Chattanooga and Hamilton County. In this section, we evaluate the impact of fiber infrastructure on employment, business investments, entrepreneurship and tax revenues in Hamilton County.

3.1 Employment Effects

The 2020 US Telecom report showcases how broadband enables at least 10 million new jobs in America alone. According to the World Bank, network externalities explain the employment effects of broadband. These effects stem from 1) improvements in productivity as a result of more efficient business processes enabled by broadband, 2) the acceleration of innovation due to new broadband-enabled applications and services, and by 3) attracting employment from other regions as a result of the ability to process information and provide services remotely. Fornefeld et al. (2008) find that these three effects act simultaneously, whereby the productivity effect and potential loss of jobs due to outsourcing are neutralized by the innovation effect and gain of outsourced jobs from other regions.

High speed broadband accelerates business development by providing new opportunities for innovation, expansion, and e-commerce developing a platform for broad-based, knowledge-driven employment in the region. The infrastructure attracts investments to the area that would not otherwise be viable to many businesses (Hasbi, 2017). The expansion of energy efficient smart grids, which require high speed communications, additionally creates new jobs and makes a location more attractive. Ford and Koutsky (2005) found that Lake County FL experienced approximately 100 percent greater growth in economic activity - a doubling - relative to comparable Florida counties since making its fiber municipal broadband network generally available to businesses and municipal institutions in the county.

Academic research has shown that broadband penetration has important economic impacts, especially on employment.[7] Middleton (2013) recommends studying features other than penetration, such as speed and quality of service because they are important determinants of the effects of broadband. Lobo, Alam and Whitacre (2019) do just this by examining the effects of broadband speed on unemployment rates in the state of Tennessee.

To estimate the incremental jobs attributable to high speed broadband in Hamilton County, we rely on estimates provided in the *Telecommunications Policy* journal article by Lobo et al. (2019). In that paper, the authors examine the effects of broadband speed on county unemployment rates in

[7] Holt and Jamison (2009) argue that broadband applications can potentially substitute for labor, make the use of labor more efficient and change the way work is done and products are produced. Broadband can affect employment through the demand for the firm's products, e.g. e-commerce. Conversely, e-commerce can also negatively affect businesses that are dependent on local market demand. For instance, competition from big online stores can hurt local retail stores. Similarly, access to home entertainment options, such as downloading or streaming movies and playing interactive video games, can decrease the demand for local entertainment options (Atasoy, 2013). Thus, it is likely that broadband technology produces "winners" and "losers" much like studies of the introduction of computers have found (Autor et al., 2003). Akerman et al. (2015) and Falck, et al. (2016) find that skilled labor benefit from ICT skills in terms of both employment and higher wages.

Tennessee over the period 2011-2015. They employ panel regressions that control for potential selection bias, reverse causality and a host of other factors that could influence the relationship between broadband speed and unemployment rates. They find that high speed broadband reduces unemployment rates by 0.26 percentage points, thereby saving or creating new jobs in a county. They also document that the average benefit to early adoption of high-speed broadband is 0.16 percentage points. In particular, they point out that in Hamilton County, TN, "*by applying a 0.26 percentage point reduction in the unemployment rate to the working age population, we get an estimate of 489 jobs saved/created each year, or roughly 2,444 jobs over a five-year period. A further adjustment of 0.16 percentage points for early adoption would raise the five-year estimate of jobs created/saved for Hamilton County to 3,948.*" [p. 10]

For the period 2011-2020, we estimate jobs attributable to high-speed broadband as follows:

> *Jobs attributable to high-speed broadband each year = Hamilton County working age population* X *(high-speed broadband effect + early adoption effect)*

Using the latest BLS population data, we estimate the number of jobs saved or newly created due to high speed broadband infrastructure in Hamilton County is 9,516. [8]

At the time of this writing, the BLS employment estimates of county jobs were only available through September of 2019. Over the period 2011–2019, the total change in private sector jobs was reported to be 23,826. Thus, the 9,516 jobs attributable to the high-speed broadband infrastructure represents 40 percent of all jobs saved or newly created in Hamilton County over the period 2011-2020.

Reasonably, one might expect that there were trade-offs in terms of jobs gained and lost in different industries with the evolution of technology (Falck, 2017). The NBN Project (2015) reported that industries/occupations most impacted by high speed broadband were gaming, health, security, entertainment, photography, smart devices, 3D printing, big data, and home working. Others find a more pronounced effect on high-tech firms and in areas with higher educational attainment (McCoy et al., 2017).

BLS sector data confirms that service-providing jobs have sharply outnumbered the goods-producing jobs in the County. **Fig 3.1** shows that over the period 2011-2020, firms in the high-tech sector generated 55 percent of net job gains, compared to 45 percent in the low-tech sector. [9] Within the high-tech sector, a large fraction of jobs were created in Professional and Business

[8] We attribute these jobs to the fiber infrastructure. To the extent that fiber is provided by the municipal utility, it is the only high-speed technology that is available to every home and office in the County. Additionally, the estimates in Lobo et al. (2019) are based on symmetrical 100+ Mbps service. Fiber broadband is the only mode capable of providing this feature. Ideally, one would separate the effects on employment of different modes of high-speed broadband in the County, e.g. fiber v copper v coaxial cable. However, this granularity of local provider data is unavailable.

[9] As a proxy for "high-tech" industries, we consider those sectors where at least 50 percent of the jobs can be done from home using the schema in Dingel and Neiman (2020). The industries best positioned for WFH are educational services, professional/scientific/technical services, management of companies and enterprises, finance and insurance, and information. The industries least well-positioned for WFH are accommodation and food services, agriculture / forestry / fishing / hunting, retail trade, construction, and transportation/warehousing.

Services, Wholesale Trade, Education & Health Services, and Financial Activities. Low-tech jobs were mostly created in Leisure & Hospitality, Transportation, Manufacturing and Construction.

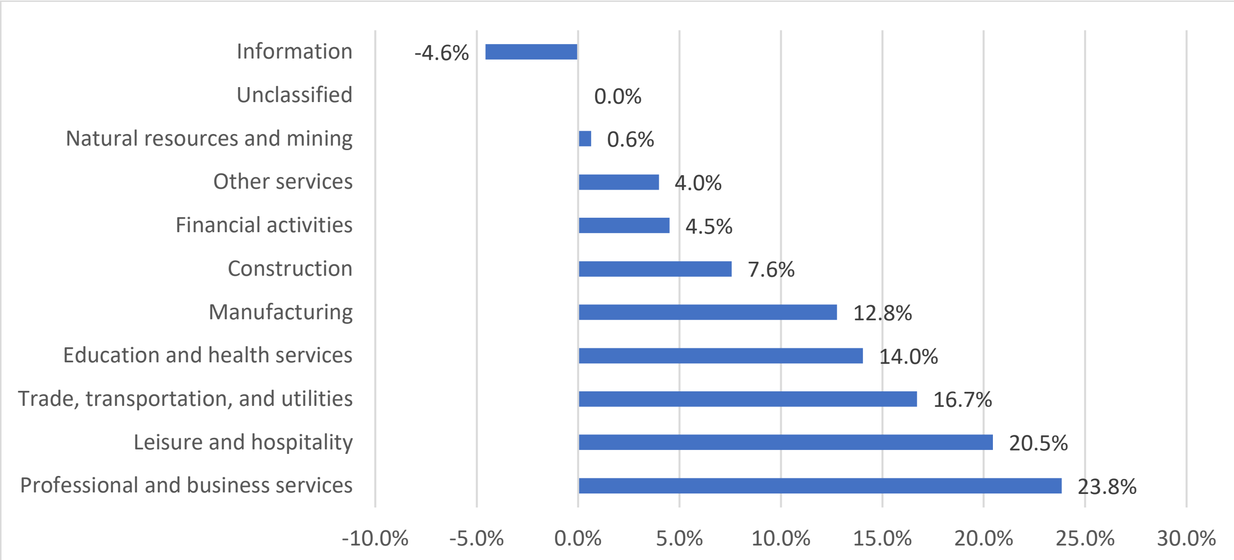

Fig. 3.1 Cumulative Change in Employment by Sector in Hamilton County (2011-2019)

3.2 Business Investments

The Chattanooga Area Chamber of Commerce collects data on announced new business investments and expansions in the community. This non-exhaustive list is compiled from news media announcements and from direct contact with potential and existing firms. The investment and job creation figures are those projected over the entire scope of the project which, in most cases, takes several years to complete. The Chamber also tracks announcements of firm closures and layoffs. Those investments that either did not materialize after the announcement or companies that have closed since announcing their original plans have been excluded from this analysis.

Among the firms reported to be investing in Chattanooga from 2011 to 2020 were Volkswagen AG (2019: $800 million and 1,000 jobs; 2014: $600 million, 2,000 jobs), McKee Foods (2020: $495 million and 482 jobs; 2015: $102.4 million, 59 jobs), Gestamp Corporation (2015: $180 million, 510 jobs), Nippon Paint (2019: $61 million, 150 jobs), and Yanfeng Automotive (2015: $55 million, 325 jobs). In 2010, Amazon invested $91 million, creating 1,249 jobs.

How much of the planned investment can be attributed to the fiber infrastructure in the community? This question is not easy to answer absent direct evidence from the relocating/expanding firms. However, evidence from corporate site selection surveys suggests that high-speed internet access and cost-efficient energy availability rank in the top 5 site-selection factors considered by firms.[10,11] This would suggest that the fiber optic infrastructure has had a significant impact in attracting companies to the area.[12]

Table 3.1 contains data on 184 announced projects over the period 2011-2020. The total value of the announced investments was $4.085 billion. About 58 percent of these firms belong to the manufacturing, professional/scientific/technical services, and health care and social assistance sectors consistent with the general pattern of investment in the county.

Table 3.1 Announced Investments and Start-up Funding

Year	Announced New Investments	Announced Start-up funding	Commercial fiber take rate	New Investments due to fiber infrastructure	Start-up funding due to fiber infrastructure
2011	$128,233,000	$23,385,000	7.3%	$9,365,808	$1,707,980
2012	$295,100,000	$127,459,618	11.4%	$33,746,260	$14,575,688
2013	$134,190,000	$61,001,331	15.9%	$21,361,747	$9,710,821
2014	$827,800,000	$290,577,701	19.3%	$159,780,948	$56,086,954
2015	$535,980,000	$100,405,182	22.2%	$119,214,218	$22,332,410
2016	$146,991,000	$122,823,811	24.9%	$36,579,099	$30,565,030
2017	$151,500,000	$185,617,100	26.4%	$40,062,991	$49,084,992
2018	$371,050,000	$131,786,711	28.4%	$105,209,819	$37,367,621
2019	$991,094,000	$76,043,504	29.1%	$288,578,270	$22,141,697
2020*	$504,000,000	$2,750,000	29.6%	$148,943,284	$812,687
TOTAL	$4,085,938,000	$1,121,849,958		$962,842,444	$244,385,880

Notes: Data on Announced Investments is from the Chattanooga Area Chamber of Commerce; Data for 2015-2019 here. * through March 2020. Start-up funding data is from Crunchbase as of April 2020 for investments located in Chattanooga.

In order to estimate the amount of new investment attributable to the fiber infrastructure in Hamilton County and Chattanooga, we consider a rough approximation similar to Lobo (2015) based on a simple assumption: To the extent that the fiber optic infrastructure (high-speed broadband and smart grid) play some role in decisions to locate investments in Hamilton County, we conservatively assume that a fraction of the announced investments equal to the commercial take rate of fiber broadband service is attributable to the fiber optic infrastructure. [13]

[10] Today, high-speed Internet access is already considered primary infrastructure by companies that handle a significant amount of electronic data. Such companies would not even consider a community without this feature. Some federal government officials have even equated it to the need for electricity in the 1930s.

[11] http://msbusiness.com/2006/07/survey-examines-top-site-selection-factors/ and http://www.utahpulse.com/featured_article/survey-site-selection-consultants-say-labor-costs-and-incentives-most-important and https://siteselection.com/issues/2011/sep/sas-optical-infrastructure.cfm

[12] Academic research shows that high-speed broadband positively impacts GDP and per capita income (Kongaut and Bohlin, 2017; Briglauer and Gugler, 2019). Others like Koutrompis (2018) additionally find evidence of nonlinear effects of higher broadband speed. Mack (2014) found that broadband speed is particularly important for firm presence in rural locations suggesting that broadband speed substitutes for the agglomerative benefits of urban locations. See also Gallardo et al. (2018) for additional references with particular emphasis on rural areas.

[13] Ideally, one would attempt to isolate the effects of the infrastructure on business investments by comparing counties with and without the infrastructure, while controlling for other factors that might additionally influence investment location. However, a lack of investment data for similar "control group" counties makes this approach difficult.

In **Table 3.1**, we show our estimate of new announced business investments attributable to the fiber optic infrastructure in Hamilton County over the period 2011-2020 is approximately $963 million.

To add perspective to this estimate of business investment attributable to fiber optic infrastructure, we note that Hassett and Shapiro (2016) find that Broadband/ICT is fairly consistently responsible for about 5.9 percent of US GDP (see their Table 1 on p.8). They conclude, "*We estimate that the use of U.S. broadband/ICT goods and services by other U.S. private industries, excluding the information sector, …[was] equivalent to 2.7 percent of their combined output and 4.0 percent of GDP. Including the government sector, these contributions by broadband/ICT to the output of other industries and sectors …[was] equivalent to 2.9 percent of their combined output and 4.8 percent of GDP*." [p. 14]. Our estimate suggests that minimally 0.43 percent of annual Hamilton County GDP can be attributable to investments attracted to the County by the fiber optic infrastructure.

An additional feature of business investment in Chattanooga pertains to real estate development. These trends are tracked by the River City Company (see **Case Study 2**) which was set up in 1986 to spur economic development in downtown Chattanooga. Importantly, **Fig 3.2** gives us a glimpse into the outside interest being generated by the City. As much as 41 percent (or $529 million) of all downtown real estate development in this period has emanated from out-of-town developers.

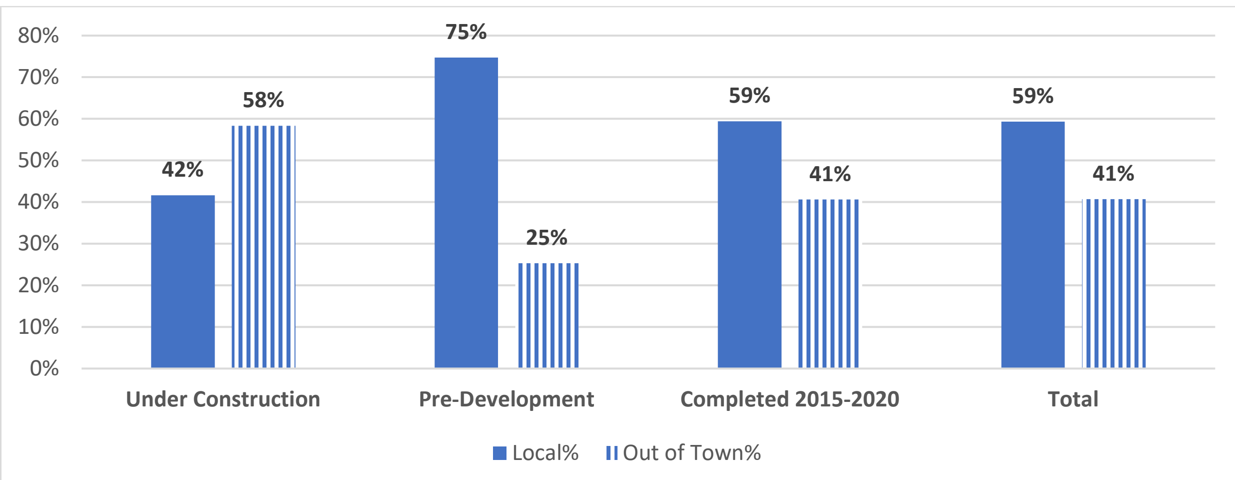

Fig. 3.2 Downtown Chattanooga Real Estate Development (2015-2020)

Case Study 2: The River City Company

The River City Company works to cultivate and advocate for a vibrant and healthy downtown and stimulates the community's economic, social and cultural growth. As part of their mission, River City maintains the most comprehensive record of real estate development in downtown Chattanooga. Their data shows that from 2015 to July 2020, approximately $1.3 billion of real estate development was either completed, under construction or in pre-development with a high probability of being completed. This activity has resulted in 1.5 million square feet of commercial property development, in addition to 3,447 apartments, 1,917 student beds, 1,812 hotel rooms and 487 condos/homes. Amy Donahue, Marketing Director of River City, believes the "*fiber optic infrastructure is a huge piece in selling the city and community. Not only does it attract developers to the area, but in turn, it helps developers attract tenants*." In the wake of the COVID-19 pandemic, Donahue believes the fiber infrastructure and high-speed broadband will become ever more attractive to relocating firms. This view is reflected by a leading local developer (see **Case Study 3**).

We estimate that some fraction of this real estate development can reasonably be attributed to the fiber optic infrastructure. Our estimate is generated by adjusting the amount of out-of-town developer investment in downtown by the average commercial fiber optic internet take rate from 2015-2020. We estimate that as much as $141.6 million of downtown real estate development can be attributed to the fiber optic infrastructure.

Case Study 3: Urban Story Ventures

Jimmy White was raised in Chattanooga. He co-founded Urban Story Ventures (USV), with Hiren Desai, in 2013 with the intention of "*creating spaces for big ideas to become big projects, for local talent to showcase their creativity, and for inspiring stories to be heard*." USV is involved with the strategic acquisition and redevelopment of Chattanooga's commercial real estate by revitalizing existing buildings and making them mixed use developments.

"*The best way to explain what we're doing with these old buildings is that we're taking a horse and a carriage and turning that into a Tesla*," said White in a 2019 interview. He bought and developed the Edney building in downtown Chattanooga, and in January 2020 sold it to Hendricks Commercial Properties out of Wisconsin. Originally built in 1953 for TVA, the 85,000 square foot Edney Building currently anchors Chattanooga's Innovation District.

White finds it much easier to sell Chattanooga to prospective tenants and clients today compared to ten years ago. "*Chattanooga is on a lot of people's radar*," he says. Even the U.S. Chamber of Commerce in Washington DC refers to the city as being in the "technology corridor". With Chattanooga making the Forbes list of most desirable cities and numerous other such accolades, White finds it easy to talk about the relative affordability, quality of life, no state income tax, and fiber optic infrastructure.

The client list includes firms from Charlotte, Chicago, Silicon Valley, Colorado, New Jersey and New Hampshire. Clients include *Day & Zimmermann* (a top 100 defense contractor), *Dennemeyer Law* (intellectual property), *CarbonFive* (code writers), and *Gannett Media*.

Chattanooga has many features that help sell itself. While Nashville has been a draw for many firms looking for affordability and quality of life, Chattanooga is benefitting partially from the spillover from Nashville. USV draws clients from Atlanta, and other nearby big cities as well, especially firms like *LMS*, a logistics firm recently acquired by FitzMark Inc, who seek the bandwidth of this city.

White says clients routinely ask about the quality of internet connectivity and the gig service in Chattanooga is a huge draw. Together with quality of the workforce, quality of life, taxes and insurance, and affordability (rents and home values), broadband speed makes up the top factors firms look for when deciding to relocate. International firms and manufacturing firms also ask about reliable power supply.

White believes the COVID-19 pandemic has actually benefited Chattanooga from a real estate standpoint. With over a half million residents leaving NYC, USV has been busier than ever in the March-June 2020 period. In fact, USV has yet to see a tenant leave after coming to Chattanooga. Instead, they have grown and scaled up operations in the area. He sees at least another 10 years of growth in the Chattanooga market.

When targeting clients to make a pitch, White's focus is on jobs. USV focuses on office and industrial clients and a few greenfield new builds such as the former location of the Alstom plant on the waterfront, known as the Bend. The proposed redevelopment of the 115-acre property could bring $2 billion to $3 billion in investments and spur more than 5,000 jobs, in addition to over $11 million in annual tax revenue (Pare, 2020).

3.3 The Entrepreneurial Ecosystem

Hunckler (2018) points out that "*Chattanooga may not seem like a market rich with startup activity, but thanks to initiatives such as a citywide fiber network, it's rebranded as an innovation hub known as Gig City*." That has attracted an impressive amount of tech innovators and even venture capital (VC) firms. This influx of entrepreneurial leadership and capital has created a diverse startup scene with companies in product development, advanced manufacturing, sales management and more. Among the many new ventures locating in Chattanooga as identified by Tech Tribune and other sources are: *Very Possible, Motivo, FreightWaves, Carbon Five, Ambition, RootsRated, Collider, Branch Technology, Skuid, Bellhops, WeCounsel, Used Equipment Guide*, and *WorkHound*.

In a 2018 analysis, PCMag attempted to break down Chattanooga's transformation into a startup tech hub (Marvin, 2018). Chattanooga appeals to a lot of the millennial workforce that's defecting from Silicon Valley and New York and looking for a change of pace. According to Bellhops CEO, Luke Marklin, Chattanooga offers a hospitable environment and an attractively low cost of living for new grads entering the workforce in addition to its natural beauty. "*We see people coming to our city knowing we have this [fiber optic] network, plus the outdoors and quality of life attributes our city has. That plus the high-speed broadband is what has brought the tech scene together*," said Chattanooga mayor, Andy Berke. Venture capitalist Santosh Sankar believes that while more intelligent infrastructure is a long-term boon for the gigabit network, the immediate benefit for startups is lightning-fast internet. The network has little-to-no latency and is far cheaper compared to the costs for similar bandwidth and speeds in a major city.

The region is home to companies in the digital media, healthcare, and software development spaces, but logistics and transportation startups are the most numerous. Two of the top 25 trucking companies, *US Xpress* and *Covenant Transport*, and a large warehousing firm, *Kenco*, are based in Chattanooga. Bandwidth-hungry logistics firms, *Steam Logistics*, *Coyote Logistics*, *Workhound*, and *FreightWaves* all call Chattanooga home. Beyond logistics startups, the area has attracted bigger tech companies like no-code, app development platform, *Skuid*, sales software startup, *Ambition*, and digital consulting agency, *VaynerMedia*.

Three of nine startup companies chosen from among hundreds of applicants for the elite Techstars Austin accelerator program in 2019 were from Chattanooga (Flessner, 2019). The local firms picked for the Texas program were *CPRWrap*, *Pass it Down* and *Woorly;* each received $120,000 in investment and training assistance along with the management training and advice offered by a variety of business and management experts from across the country.

International Maritime Security Associates (IMSA) cited the speed and reliability of the gig network as a big factor in the company's decision to relocate from South Florida to Chattanooga (see **Case Study 4**). Similarly, the broadband infrastructure appealed to the organizers of the Alexa Conference, which attracted developers for Amazon's cloud-based voice service, who came to Chattanooga from around the world in January 2018 to share thought leadership and best practices. The infrastructure similarly explains *Branch Technology*, which took the top prize in a NASA competition designed to advance the construction technologies necessary to create off-world habitats. Additionally, in October 2017, Chattanooga hosted the inaugural TENGIG Festival – produced in partnership with EPB Fiber Optics, Vayner Media and Next Generation Esports – a three-day event in which hundreds of attendees gathered to play and stream the biggest games in eSports.

Case Study 4: International Maritime Security Associates, Inc

Corey Ranslem, Coast Guard veteran and Frank Fenner, Navy veteran, saw a need for more integrated, immediate information for those operating on the high seas. They co-founded IMSA in Fort Lauderdale, Fla. in 2013. Their Automated Risk Management Solution (ARMS) software provides real-time, location-specific critical information to mariners. The company also provides other maritime related services including cyber security, maritime regulatory compliance and maritime security.

Chattanooga is more than 400 miles from the nearest ocean, but IMSA chose to move its software operations, development and data center there because of the city's high-speed internet links, reliable power and low cost of living (Flessner, 2017). In 2017, IMSA was recognized by the Chattanooga Technology Council (CHATech) with the "Early Innovator Award".

At any given time, there are roughly 55,000 vessels on the oceans. The Global Maritime Distress and Safety System (GMDSS) broadcasts information about weather and other shipping transportation activities, but the system texts, beeps and squawks about events all over the world constantly. Vessels often receive irrelevant data and miss important news because the system is overwhelming. IMSA cuts through the noise with information regarding news about ports/canals/waterways, civil unrest, maritime security, major weather events, medical epidemics, cyber monitoring for onboard issues, and the "plus one" category, i.e. plotting text information from GMDSS into a path-map.

"*It is as if the fiber optic infrastructure in Chattanooga was built for us*," says Ranslem. IMSA is a big data company with about 80 employees and contractors. They assemble information from thousands of sources around the globe, parse the information, and customize the output for clients. The need for bandwidth is significant, especially for inbound or "download" capacity. As they start to ramp up their cyber security service, it will eventually be consuming bandwidth in the terabytes.

The gig service from EPB currently provides them the needed capacity. Due to the sensitive nature of their business they maintain local servers rather than cloud-based storage. The reliability and redundancy of the internet service is very valuable to IMSA. The downtime from a natural disaster could cost clients millions of dollars. The reliability of the fiber infrastructure in Chattanooga was a key determinant in the move.

According to Ranslem, "*You can't find [the internet infrastructure] for what we're going* *to be able to do here anywhere in the world*." Coming from South Florida, the annual cost of a fiber connection was in the tens of thousands of dollars, and reliability was not guaranteed. The added cost of real estate made the decision to move to Chattanooga an easy one.

Over the next five years IMSA's inbound data usage could reach 5 gigs/second; Outbound data will be less because of how their platform works. This data usage includes the ARMS platform along with all of their cyber security related services. Files of all different types and sizes will be used including, audio, video, pictures, and text data. Ranslem said, "*The cost for this type of connection in South Florida or almost anywhere else in the world would be so prohibitive for a company our size. That is the main reason why we have this part of our company here in Chattanooga. This type of infrastructure is going to save us millions of dollars in operational costs as we haven't found any type of infrastructure that is as reliable as EPB here in Chattanooga for the price.*"

Dixon (2016) reported that Chattanooga ranked highest as the city with the lowest startup costs in the U.S. The study found that the cost of running a business in the first year in Chattanooga is half that of Silicon Valley, with the cost of office space and utilities (including EPB's gig network) playing a key role in the city's affordability.

Jackson et al, (2016) credit the gig as one of four key reasons why Chattanooga has cultivated such a dynamic entrepreneurial hub. Feloni (2018) too, points out that Chattanooga has found a way to reinvent itself as a startup center of the South on the back of "city-operated high-speed internet and pro-entrepreneur policies." Zasky (2018) echoes this opinion in explaining why entrepreneurs and tech startups are flocking to Chattanooga: it's not just that the broadband is available at a very affordable price, but also a really strong support system for entrepreneurs.

Part of this ecosystem comprises CO.LAB accelerator (see **Case Study 5**), which has been described as "the front door for entrepreneurship in Chattanooga," to the INCubator, which houses the Tennessee Small Business Development Center, to The Enterprise Center which leads development of Chattanooga's downtown Innovation District, a collection of business incubators and accelerators. [14, 15] Additionally, the Chattanooga Smart Community Collaborative brings together the city of Chattanooga, Hamilton County, The University of Tennessee at Chattanooga, Erlanger Medical Center, CoLab and EPB under the direction of the Enterprise Center to address community issues with community resources. Morrison and Bevilacqua (2019) describe the evolution of Chattanooga and the efforts of public and private actors to limit the negative externalities of the Innovation District via socio-economic, urban and housing strategies.

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[14] http://www.chattanoogan.com/2015/1/13/291936/Chattanooga-Is-First-Mid-Size-City-To.aspx

[15] An entrepreneurial ecosystem comprises a set of interdependent actors and factors that are governed in such a way that they enable productive entrepreneurship within a particular territory. Leendertse et al. (2020) characterize entrepreneurial ecosystems by operationalizing ten elements of entrepreneurial ecosystems. Their results show that formal institutions and physical and digital infrastructure have a central place in the interdependence web, providing a first indication of these elements as fundamental conditions of entrepreneurial ecosystems.

Case Study 5: The Company Lab (CO.LAB)

CO.LAB is a nonprofit startup accelerator that supports entrepreneurial growth in Southeast Tennessee. The organization helps connect entrepreneurs with expertise, resources, and community.

The Kauffman Foundation's report "*Little Town, Layered Ecosystem: A Case Study from Chattanooga*," concludes CO. LAB's efforts have resulted in a diverse economic atmosphere which provides substantive support for Chattanooga entrepreneurs.

CO.LAB has helped program participants with networking opportunities, entrepreneur education & training, entrepreneur inspiration & encouragement, referrals to other local entrepreneurial support organizations, and technical business assistance. The list of its accomplishments is impressive.

- CO.LAB program alumni have founded 221 companies in the year immediately prior to or following their first participation in a CO.LAB program.
- 74% of companies founded by CO.LAB program participants that are still in existence are Small or Medium Business Enterprises (SMEs) and 26% are Innovation-Driven Enterprises (IDEs).
- A small subset (58 companies) of the companies founded by CO.LAB program participants self-report that they currently employ 323 full-time employees and 283 part-time employees. These companies also engage 170 full-time independent contractors and 223 part-time independent contractors.
- CO.LAB program participants have raised at least $120.7 million of capital (from all sources), including more than $83 million in equity investments.
- CO.LAB's most intensive programs, GIGTANK and Accelerator, provide an opportunity for local technical and creative talent to engage in entrepreneurship.
- CO.LAB-developed programming and events focus on eleven distinct industries and issues, including software and application development, smart grid applications, 3-D printing, healthcare, tourism, education and workforce development, social innovation, female-founders, internet of things, outdoors and recreation, and music and entertainment. These efforts supported the development of more than 50 startups across the 11 sub-ecosystems.
- CO.STARTERS, a replicable program created by CO.LAB to guide entrepreneurs through lean startup-inspired strategies, was licensed locally by multiple organizations for use in their work with startup founders. It is now used by nearly 70 startup locations across globe.
- The organization actively seeks to promote inclusivity through its programs and has achieved a positive trendline in the participation rates of women and minorities in its programs.

Over a six-year period, CO.LAB's efforts spurred additional international, national, regional, and local media coverage to strengthen Chattanooga's recognition as an emerging entrepreneurial ecosystem. The advertising equivalency value for the media coverage they have received is estimated to total $7.02 million.

A Kaufmann Foundation 2019 report said, "*Ecosystem builders work to make their communities a great place to start and grow a business by breaking down barriers for all entrepreneurs. This network of support can create an inclusive homegrown economy where everyone benefits.*" The evolution of the entrepreneurial ecosystem in Chattanooga is especially remarkable because the city does not have a tier-1 research University, unlike Austin, TX, for instance. However, the technological transformation in Hamilton County and Chattanooga in particular, has resulted in the development of a unique entrepreneurial ecosystem.

A distinctive culture of public-private partnerships in Chattanooga has led to the rapid development of innovation, entrepreneurship and venture funding. As of March 2020, there were several venture/angel funds headquartered in Chattanooga such as Jump Fund, Solas Bioventures, Dynamo Capital, Blank Slate Ventures and Chattanooga Renaissance Fund. From coffee shops to emerging technologies, nonprofits and a UX (user experience) design school, Chattanooga entrepreneurs have used crowdfunding to get their ideas off the ground and rally the community to their causes (Shaughnessy, 2015). According to Kickstarter statistics, Chattanoogans have produced a higher percentage of acclaimed crowdfunded projects than almost every other Southeastern city Phillips (2016). In Chattanooga, 10.1 percent of the 287 Kickstarters created here have been designated as "Projects We Love", i.e. Kickstarters' "best-in-class projects" as determined by the website's staff. The Scenic City has a higher percentage of awarded projects than in most regional cities, including Nashville (7.7 percent), Birmingham, Ala. (7.2 percent), Atlanta (6.5 percent), Huntsville, Ala (4.6 percent) and Knoxville (3.9 percent).

Venture Density

A recent metric of entrepreneurship comes from Mossberger et al. (2020) who use data on over 20 million ventures in the United States, defined as domain name websites and their redirects, to measure digital engagement.[16] Based on the number of active domain names (i.e. websites) registered with GoDaddy, venture density is measured per 100 people. The authors point out that, "*Activities on the internet are an expression of "digital citizenship" or an individual's ability to participate in society online…. [Such] digital participation in communities requires broadband access, adoption, digital skills, and technology use.*" Their analysis leads them to conclude that digital resources make it possible to build more prosperous communities and economic opportunity for all, beyond the limited number of superstar cities with concentrations of technology firms.

The available data is for the period from May 2018 to December 2019. **Fig 3.3** shows that Hamilton County's digital entrepreneurial engagement is roughly 2.2 times the national average. The median number of ventures per 100 residents is 4.46, while the number of highly active ventures is 1.1 compared to national averages of 2.1 and 0.5, respectively.[17] These statistics highlight the importance of public policy to reduce the digital divide and the associated skills divide. In relative terms, Hamilton County is better off than most counties in the country.[18]

[16] Ventures may be businesses, nonprofits, causes or ideas that owners put online.

[17] "Activity is measured by venture age, demand (How busy is the venture in terms of traffic and economic footprint with commercial data?), by connection (How networked is the venture across the internet, both in links and out-links?), and by breadth (How built-out is the venture? Have there been upgrades, downgrades or products added or subtracted?)." [p.8]

[18] Hellinghausen (2018) draws attention to the need for local entrepreneurship data. Along these lines, work done at Deloitte to develop how business investments socially impact on community concerns such as poverty,

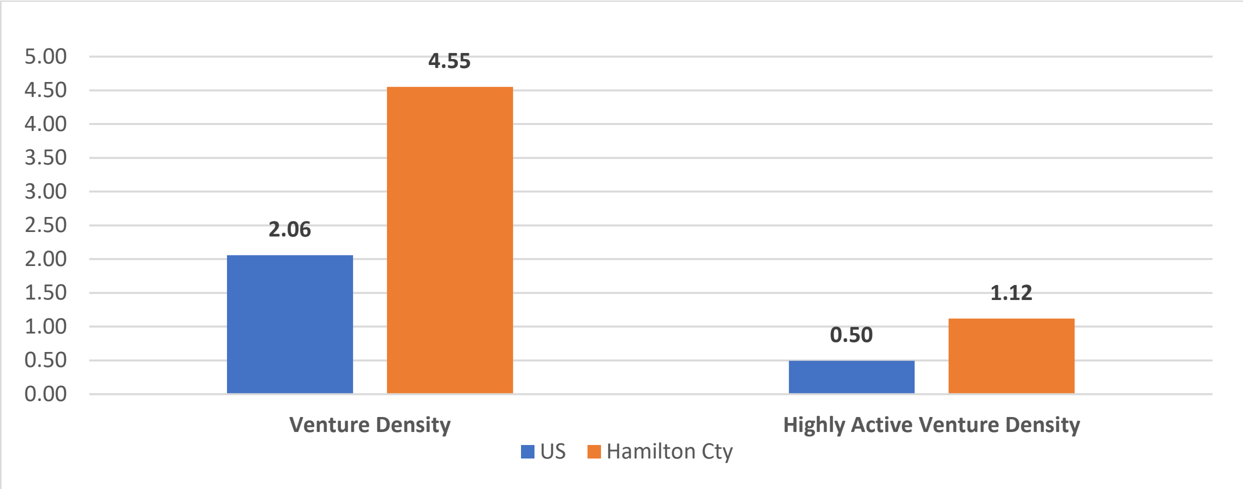

Fig. 3.3 Hamilton County Digital Entrepreneurial Engagement (2018-2019)

As a gauge of the impact of the fiber optic infrastructure on entrepreneurship, we examine data from Crunchbase on start-up funding (including equity and product crowdfunding). Available data shown in **Table 3.1** for investments located in Chattanooga indicates that this funding totaled $1.12 billion over the period of this study.[19] Conservatively, we apply the commercial fiber take rate to the startup investments and find that approximately $244 million of start-up funding may be attributable to the fiber optic infrastructure over the study period.

3.4 Taxes

The fiber optic division of EPB, comprising video & internet and telecom services, has contributed to city and county coffers in the form of payments in-lieu of taxes (PILOT). Additionally, a portion of the EPB electric division's PILOT is also attributable to the fiber infrastructure. The total amount of payments in-lieu of taxes contributed by the fiber optics division over the period from 2011 to 2020 was $59.9 million, as seen in **Table 3.2**.[20]

Summary

In sum, we estimate that the fiber optic infrastructure impacted local economic development to the extent of $1.41 billion in business investments, new startups, real estate development and taxes, in addition to creating/saving 9,516 jobs.

homeownership, educational attainment, public health, and civic engagement could be useful. Ellis et al. (2018) describe their Social Impact Measurement Model (SIMM) based on a machine-learning model which estimates the social impact of investments at the US county level for the four years following the investment as a guide to better decision-making.

[19] Care was taken to avoid overlap in the Chamber's listing and the Crunchbase listing of firms.

[20] Note that the taxes contributed to city and county coffers due to the fiber optic infrastructure are likely to be higher than reported here because private business growth is not considered. To the extent that high-speed broadband and the smart grid have contributed to economic development, some portion of private business taxes paid to the county might reasonably be attributed to the fiber infrastructure.

Table 3.2 EPB Payments In-Lieu of Taxes due to Fiber Optic Infrastructure				
	EPB Business Divisions ($000s)			
	Fiber Optics Division		**Electric**	**Total**
	Video & Internet	**Telecom**		
FY 2011	$465	$947	$2,612	$4,024
FY 2012	$641	$906	$3,838	$5,385
FY 2013	$759	$817	$4,075	$5,651
FY 2014	$803	$742	$4,153	$5,698
FY 2015	$915	$679	$4,389	$5,983
FY 2016	$929	$665	$4,518	$6,112
FY 2017	$977	$679	$4,799	$6,455
FY 2018	$1,088	$730	$5,033	$6,851
FY 2019	$1,158	$763	$5,118	$7,039
FY 2020§	$1,200	$758	$4,767	$6,725
Total	$8,935	$7,686	$43,303	$59,924
Source: EPB Annual Reports. § estimates provided by EPB.				

CHAPTER 4. SMART GRID EFFECTS

The U.S. Department of Energy's (DOE) website, smartgrid.gov, describes the electric grid as a network of transmission lines, substations, transformers and more that deliver electricity from the power plant to one's home or business. [21] What makes a grid "smart" is the digital technology that allows for two-way communication between the utility and its customers and its critical equipment. Like the internet, the Smart Grid consists of controls, computers, automation, and new technologies and equipment working together. These technologies work with the electric grid to respond digitally to quickly changing electric demand. Fiber optic infrastructure is critical to the working of a smart grid.

A smart grid permits a cleaner and more resilient and efficient electrical system. As pointed out in Lobo et al. (2011) the Smart Grid plays an important role in mitigating electrical system emergencies, avoiding blackouts and increasing system reliability, reducing dependency on expensive imports, providing relief to the power grid and generation plants, avoiding high investments in generation, transmission and distribution networks and thereby leading to environmental protection.

The DOE cites the following benefits of a Smart Grid:

- More efficient transmission of electricity
- Quicker restoration of electricity after power disturbances
- Reduced operations and management costs for utilities, and ultimately lower power costs for consumers
- Reduced peak demand, which will also help lower electricity rates
- Increased integration of large-scale renewable energy systems
- Better integration of customer-owner power generation systems, including renewable energy systems
- Improved security

In 2008, EPB began modernizing the electric system and constructing one of the first and largest Smart Grids in the United States. The Smart Grid called for new capital expenditure of $163.2 million over five years for fiber optic build-out, additional electronics, distribution automation, SCADA upgrade and the AMI initiative (Glass et al., 2015). In November 2009, EPB received a federal stimulus matching grant in the amount of $111.6 million from the Department of Energy to expedite the implementation of the Smart Grid.

The smart grid was built out and became fully operational in 2012. In this chapter, we report on metrics for the period 2012-2020. It bears noting that as a city-owned utility, the benefits attributed to EPB on account of the smart grid effectively accrue to the community that EPB serves. For instance, the benefits from stemming the costs of major weather events accrue mostly to businesses and households in terms of a reduction in lost productivity and economic activity. However, we include these benefits in this section of the paper because they are attributable to the smart grid infrastructure.

[21] Our current electric grid was built in the 1890s and improved upon as technology advanced through each decade. Today, it consists of more than 9,200 electric generating units with more than 1 million megawatts of generating capacity connected to more than 300,000 miles of transmission lines.

4.1 Reduced operating and maintenance costs

The utility has realized operational cost savings through automation of meter reading, remote disconnects/reconnects, and planned switching events. The automated switching has significantly reduced the need to send staff into the field during and after storms to identify damage locations, isolate the damage, and restore the affected sections. The savings are realized in terms of fewer truck rolls and miles covered, as well as reduced fuel and labor costs. Note that data is only available from 2014 on.

In **Table 4.1**, we see that over the period 2014-2020, the benefits of automated meter reading, remote disconnects/reconnects and planned automated switching aggregate to $14,074,513. The cost savings include vehicle, labor and fuel costs associated with these activities. The smart grid has resulted in EPB operators driving 2,457,154 fewer miles due to automation. The reduction in miles driven is addressed later when discussing pollution reduction effects.

Table 4.1 Meter Read and Switching Cost Reductions

	Meter Reads Avoided		Remote Disconnect/Reconnect		Planned Switching Events	
	# AMI Meters	# Miles Avoided	# Events	# Miles Avoided	# Events	# Miles Avoided
2014	2,092,032	251,044	-	-	6,577	13,154
2015	2,092,032	251,044	19,590	54,852	8,038	16,076
2016	2,092,032	251,044	46,806	131,057	10,613	21,226
2017	2,092,032	251,044	53,853	150,788	13,164	26,328
2018	2,144,442	257,333	57,052	159,746	10,592	21,184
2019	2,196,852	263,622	63,022	176,462	10,652	21,304
2020	732,284	87,874	15,614	43,719	4,127	8,254
Total	13,441,706	1,613,005	255,937	716,624	63,763	127,526
Cost Reduction	$9,409,194		$3,071,244		$1,594,075	

Source: EPB. Assumptions: Cost per meter read = $0.70; cost per remote disconnect/reconnect = $12; cost per switch = $25; Cost per AMI work order = $9.87. Data for 2020 through to April.

4.2 Outage reduced

The single largest benefit of the smart grid has been in substantially reducing outage minutes brought on either by a storm or other non-storm factors. During major and minor storms or disruptions of any kind, the smart grid enables a quick diagnosis and often, a remote solution. Outages can be measured in terms of customer minutes and customer interruptions. [22] Over the period of study, EPB had achieved a 43 percent reduction in outage minutes on average (see **Fig. 4.1**).

[22] For each electric outage, EPB records the number of customers affected and the length of the outage. The number of customers affected multiplied by the length of the outage equals the "customer minutes" of outage. Customer Minutes Avoided is the number of minutes of outage that have been reduced due to the automation.

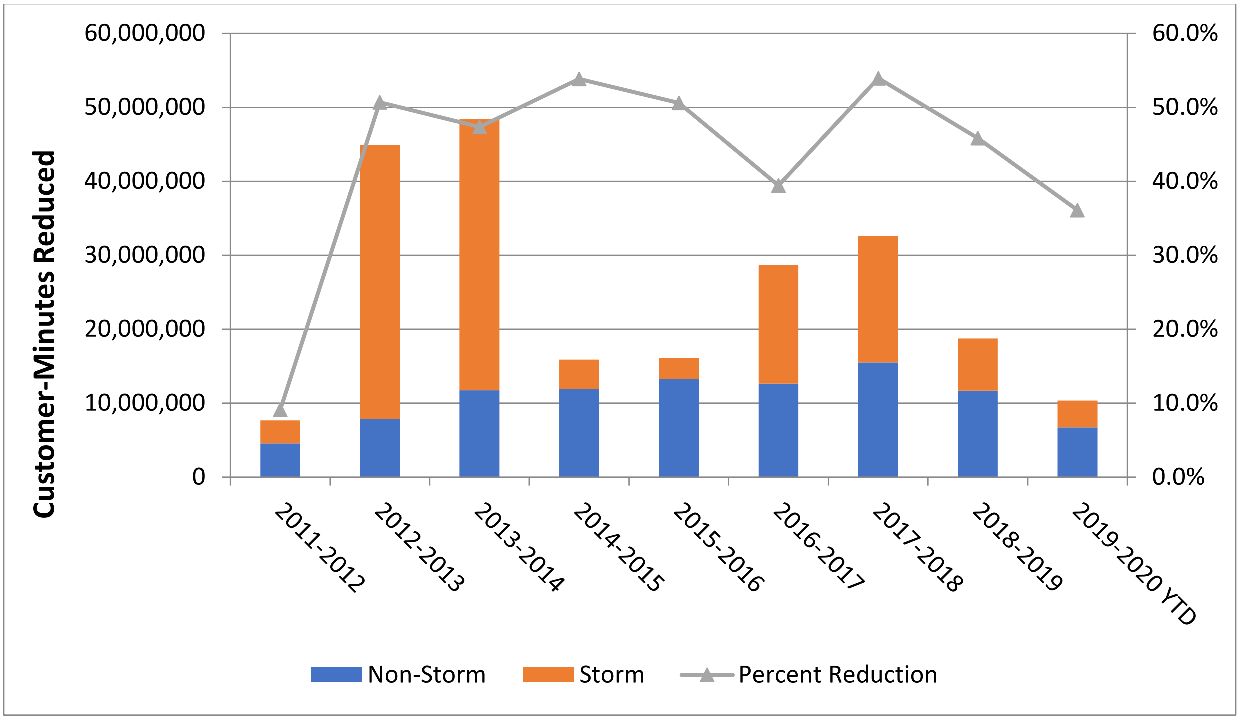

Fig. 4.1 Electric System Automation Benefits

Table 4.2 shows that as much as 281.1 million customer (residential and commercial) minutes of outage time were avoided, which when divided by 480 (minutes/workday) shows that roughly 585,643 work-days were saved due to the smart grid. Table 4.2 also shows customer interruptions avoided, i.e. customers that were automatically restored (usually in a few seconds) or customers that did not experience an outage at all who would have previously without automation. From 2011 through April of 2020, about 2.11 million customer interruptions were avoided due to the smart grid.

Table 4.2 Electricity Outages Reduced

	Customer Minutes Avoided			**Customer Interruptions Avoided**		
	Storm	**Non-storm**	**Total**	**Storm**	**Non-storm**	**Total**
2012	3,096,757	4,570,752	7,667,509	31,505	83,607	115,112
2013	36,976,226	7,905,058	44,881,284	42,589	129,846	172,435
2014	36,633,684	11,741,673	48,375,357	45,774	195,032	240,806
2015	3,949,200	11,928,864	15,878,064	28,484	197,361	225,845
2016	3,628,740	13,631,310	17,260,050	29,687	205,090	234,777
2017	15,991,292	12,654,002	28,645,294	140,451	185,043	325,494
2018	20,487,050	19,526,335	40,013,385	298,864	258,133	556,997
2019	7,062,181	11,683,835	18,746,046	77,798	159,364	237,162
2020	45,999,539	9,206,787	55,206,326	88,973	133,573	222,546
Total			281,108,405			2,372,655

Source: EPB. Data for 2020 is through to April. Customer interruptions are # customers interrupted per event

We use the DOE's Interruption Cost Estimate (ICE) calculator to calculate the economic effect of non-storm outage minutes and customer interruptions saved. [23] The ICE calculator is designed to provide a snapshot of costs to customers (residential, commercial and industrial in different geographic footprints) of electric outages based on utility metrics such as System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI) and Consumer Average Interruption Duration Index (CAIDI). To derive the economic value of utility efficiency, i.e. outages and interruptions avoided, one would compare the ICE estimates from prior to automation relative to post-automation. We examine costs of outages/interruptions to customers at two points in time: June 2011 (before the smart grid became operational) and February 2020.

Table 4.3 ICE Calculator Results

	SAIDI	SAIFI	Cost to Customers	Improvement = Annual Cost Savings
June 2011(without automation)	112.0	1.42	$58,013,714	$26,648,969
February 2020 (with automation)	72.3	0.61	$31,364,745	
Note: Other inputs: non-residential customers = 30,000; residential customers = 155,000				

Table 4.3 shows that the annual cost savings due to the smart grid amounts to $26.65 million. Over a nine-year period, this benefit amounts to $239,840,719. This sharp improvement in system reliability is seen in the SAIDI metric shown in **Fig. 4.2.** After automation, EPB has moved up to being amongst the most efficient utilities in the country.

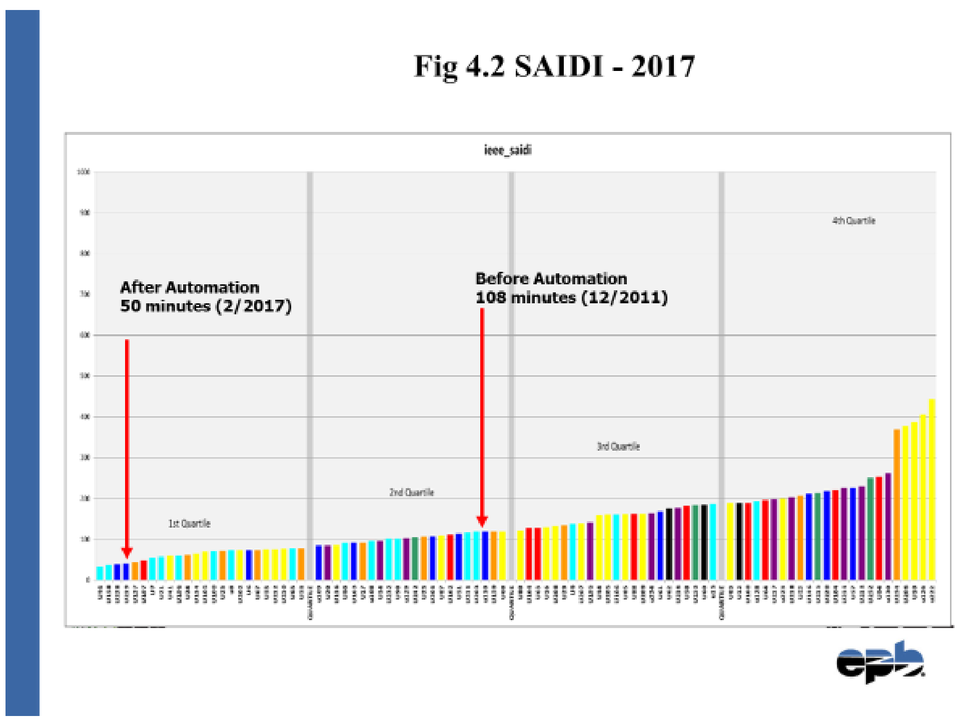

Fig. 4.2 EPB SAIDI - 2017

[23] Cost estimates for various customer types are based on a combination of surveys and econometric models (Sullivan et al., 2018).

Case Study 6: The Tornados of April 2020

As tornados, heavy storms, and high winds rolled across the community after 11 p.m. on Easter Sunday (April 12, 2020), more than 106,000 EPB customers lost power. EPB estimated that this storm resulted in more than $28 million in damage to the community's electric and fiber optic infrastructure, exceeding the $25 million damage from the tornados that impacted the area in 2011.

Almost instantaneously, Chattanooga's smart grid began its automated processes which prevented about 44,000 customers from experiencing an outage that would have lasted hours or perhaps days.

EPB noted that the smart grid allowed the utility to immediately focus on repair efforts for about 62,000 customers who remained without power. Within 24 hours, EPB had restored power to 20,000 more households while beginning the process of calling on mutual aid agreements with other utilities.

Major weather events: The ICE calculator does not tell the whole story of utility efficiency because it does not factor in major weather events such as the tornadoes of April 2020.[24] A joint EPB-Oak Ridge National Lab study (Glass et al., 2015) of a major event on July 12, 2012 revealed that with automation, EPB was able to reduce customer outages by 56 percent and outage costs by 33 percent. The overall avoided cost from outages due to major events was estimated to be $23.4 million per event. At an average of two major weather events per year (totaling an average of 5-6 days of outages), the total benefit from smart grid automation during major weather events amounts to $421,200,000 over the 9-year period 2012-2020.

4.3 Demand-side management and reduced peak demand

The Smart Grid facilitates the use of automated switching and demand-side management (DSM) programs which help to shave peak load and lower the cost of power. DSM provides significant economic, system reliability and environmental benefits. Reduced energy usage can directly translate into less air pollution, less carbon emissions, and a way to lower the potential environmental threats associated with climate change, even though off-peak energy needs are typically met from coal facilities (Lobo, 2015).

Peak reduction data is available from 2014. With the smart grid, EPB was able to reduce peak demand by 25-30 MW per month. Additionally, voltage reduction of 2-3 percent on each circuit allowed EPB to reduce peak energy consumption by an average of 1-2 percent per month. As an example, in 2019 alone, EPB reduced energy consumption by 825 MWh. For the period 2014-2020, the utility was able to shave 1,865 MW of demand and 10,331 MWh of electricity consumption (see **Table 4.4**).

To calculate the savings associated with peak demand reduction, we apply an average price of $10,900 per MW based on average TVA wholesale prices over the study period. The savings amount to $20.3 million over the period 2014-2020.

[24] A major weather event is defined as an event that causes 10% or more customers in a defined geographic district in the utility footprint to experience an outage.

Additional environmental benefits can be attributed to the reduction in energy (MWh). In **Table 4.4** we show the amounts of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) reduced by lowering the amount of peak energy consumed each year. We discuss these effects next.

Table 4.4 Peak Demand, Energy and Pollution Reduction

	MW Reduced	Cost of MW saved	MWh Reduced	Pollutants Reduced (tons)		
				CO_2	CH_4	N_2O
2014	269	$2,930,356	1,903	-901.99	-0.038	-0.021
2015	301	$3,284,715	2,183	-1,034.55	-0.044	-0.025
2016	303	$3,299,812	2,390	-1,132.98	-0.048	-0.028
2017	275	$3,000,814	1,743	-825.97	-0.035	-0.020
2018	310	$3,380,439	964	-462.35	-0.018	-0.013
2019	319	$3,475,247	825	-391.22	-0.018	-0.011
2020	88	$954,055	323	-63.76	-0.003	-0.002
Total	1,865	$20,325,437	10,331	-4,812.82	-0.20	-0.12

Note: Cost/MW = $10,900 based on TVA wholesale rates as provided by EPB. Data for 2020 is through to April.

4.4 Pollution reduction

Models from the World Resource Institute show that EPB's peak demand reduction resulted in reducing carbon-equivalent (CO_2E) pollutants by 4,848 tons over the period 2014-2020. This is in line with the EIA's estimates showing electricity accounts for 78 percent of commercial CO_2 emissions. Similarly, the avoided miles driven due to automation (**Table 4.1**) results in reduction in pollutants to the extent of 3,129 tons of CO_2E.

The EPA and other federal agencies use estimates of the social cost of carbon (SC-CO_2) to value the climate impacts of emissions. The SC-CO_2 is a measure, in dollars, of the long-term damage done by a ton of carbon dioxide (CO_2) emissions in a given year. The SC-CO_2 is meant to be a comprehensive estimate of climate change damages and includes changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning. These federal agencies also use estimates of the social cost of methane (SC-CH_4) and the social cost of nitrous oxide (SC-N_2O) in analyses of regulatory actions that are projected to influence CH_4 or N_2O emissions in a manner consistent with how CO_2 emission changes are valued. The models used to develop these social cost estimates, known as integrated assessment models, do not currently include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature because of a lack of precise information on the nature of damages and because the science incorporated into these models naturally lags behind the most recent research.

Table 4.5 shows the reduction in emissions of carbon dioxide, methane and nitrous oxide due to reduced peak demand and avoided miles. Based on the per ton cost of each of these pollutants, the aggregate socio-economic benefit of reduced pollution amounts to $359,362.[25]

[25] This estimate is calculated differently from Lobo (2015) because costs of pollutants were not readily available five years ago.

Table 4.5. Pollution Reduction Benefits							
	Emissions Reduced (tons)				Value of Reduced Emissions		
	CO_2	CH_4	N_2O		CO_2	CH_4	N_2O
					$43/ton	$1,200/ton	$15,000/ton
2014	-1,296.50	-0.050	-0.021		($55,750)	($60)	($315)
2015	-1,513.37	-0.056	-0.025		($65,075)	($67)	($375)
2016	-1,730.55	-0.060	-0.028		($74,414)	($72)	($420)
2017	-1,459.91	-0.047	-0.020		($62,776)	($56)	($300)
2018	-1,111.06	-0.030	-0.013		($47,776)	($36)	($195)
2019	-1,073.86	-0.030	-0.011		($46,176)	($36)	($165)
2020	-122.42	-0.004	-0.002		($5,264)	($5)	($30)
Total	(8,307.66)	(0.277)	(0.120)		($357,229)	($332)	($1,800)
Source: Pollutant estimates from World Resource Institute as provided by EPB. Cost estimates from Marten et al. (2015)							

Case Study 7: Chattanooga cuts carbon emissions by more than 25%

A study by paleBLUEdot LLC released in July 2020 showed the amount of greenhouse gases emitted in Chattanooga dropped from nearly 4 million metric tons in 2008 to less than 3 million metric tons a decade later. The 25.2% decline in carbon output came from reduced energy and wastewater pollution, even with a 14.3% gain in the city's population and a 44.8% growth in Chattanooga's economic output (Flessner, 2020c).

In 2011, the city of Chattanooga was among more than 125 local and state governments — and among more than 900 organizations nationwide — that signed up for the Department of Energy's Better Buildings Initiative and its Better Buildings Challenge to reduce their energy consumption by 20 percent by 2025.

The analysis of Chattanooga's pollution and land practices showed the city made major gains in the past decade in cutting carbon emissions used for its electricity and other energy and in reducing energy and wastes in its sewage treatment processes.

"*The solar installation at the Moccasin Bend Wastewater Treatment Plant, the public safety 'microgrid' project on Amnicola Highway, and our coordinated resiliency planning with our regional government partners are all part of a larger strategy to boost our economy and drive down carbon emissions*," said Chattanooga mayor Andy Berke.

4.5 Reduced costs from theft

Remote meter reading allows for more frequent identification of electricity theft. EPB estimates this benefit to be roughly one percent of annual revenues or $50.55 million over the period 2012-2019 (see **Table 4.6**).[26]

[26] A more robust methodology for calculating this theft would be to calculate the Non-Technical System Losses as the difference between Total System Loss and Technical Losses. Moreover, the incremental benefit of the smart grid would have to be evaluated relative to system losses prior to AMI installations. However, these estimates were not available at the time of this writing.

Table 4.6 Power Theft Reduction					
Year	Electric Revenues ($000)	Theft Reduction (1%)	Year	Electric Revenues ($000)	Theft Reduction (1%)
2012	$558,125	$5,581,250	2017	$567,035	$5,670,350
2013	$552,627	$5,526,270	2018	$567,058	$5,670,580
2014	$564,623	$5,646,230	2019	$570,576	$5,705,760
2015	$553,139	$5,531,390	2020§	$572,259	$5,722,590
2016	$549,421	$5,494,210	Total		$50,548,630
Source: EPB Annual Reports and author calculations. § estimate.					

4.6 Other Societal Benefits

"*Once mature, the Smart Grid will likely bring the same kind of transformation that the Internet has already brought to the way we live, work, play, and learn.*" (smartgrid.gov)

A modernized Smart Grid allows for environmental and health benefits, but also enables connection of distributed generation (with photovoltaic arrays, small wind turbines, micro hydro, or even combined heat power generators in buildings); incorporating grid energy storage for distributed generation load balancing; and eliminating or containing failures such as widespread power grid cascading failures (Lobo, 2015). The digital devices within the grid can decide how to best allocate power, depending on the demand, and they may be able to control devices attached to the grid. [27]

As a testament to the effectiveness of the Smart Grid in Chattanooga, the DOE, Oak Ridge National Laboratory (ORNL) and EPB announced in October 2014, the beginning of a partnership that would use Chattanooga's smart grid as a living laboratory for testing new energy technologies. Since then, Georgia Tech, UT Chattanooga and UT Knoxville have signed MOUs to form similar bilateral partnerships.

Under the agreement with EPB and DOE, the ORNL applies its technical expertise in such areas as data analytics, control systems, cybersecurity and high-performance computer modeling to test new smart grid technologies and processes on the electric grid in Chattanooga, allowing EPB to further capitalize on its smart grid investment.

Flessner (2020d) reports that top researchers in quantum physics from the Los Alamos National Laboratory and the ORNL tested a new CEDS (Cybersecurity for Energy Delivery Systems) system that uses quantum technology to encrypt messages sent along EPB's smart grid. This project when completed would make the electric grid much safer and less vulnerable to cyberattacks than any existing controls. The ORNL researchers were attracted to EPB because of its citywide fiber optic network and the utility's willingness to share in research efforts, including its Engineers Scholars program.

[27] In a simple example, a smart grid would recognize that a lot of people in one area were running air conditioners because it was hot, and opt to shuttle more power to that part of the grid. Furthermore, the smart grid might have the ability to shut down unused escalators and elevators in commercial buildings to free up power, or to adjust thermostats used for climate control to make energy usage more efficient.

EPB continues to explore other applications of its smart grid including microgrids with flexible boundaries, networked microgrids, optical sensors for substations, battery energy storage, and unmanned aerial vehicles to name a few.

In sum, over a period of just under nine years, EPB's smart grid has generated economic value of $750.16 million for the community it serves. **Fig. 4.3** presents a summary of the factors contributing to the value of the smart grid.

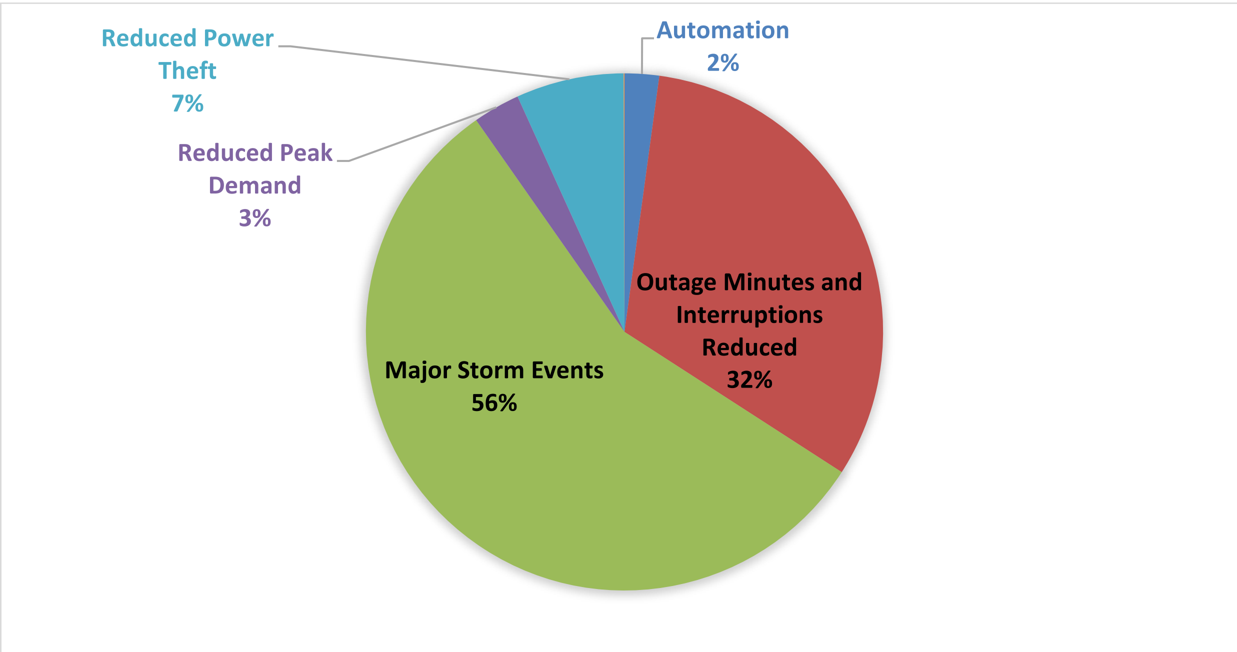

Fig. 4.3 The Value Components of the Smart Grid

CHAPTER 5. BUSINESS EFFECTS

Today, all business is e-business. E-business refers to the integration of information and communications technology into every stage of the value chain and includes the use of advanced information and communication technology (ICT) to attract and retain customers, to streamline firm operations such as supply chain or inventory management, to automate business processes, and to collect, analyze and share business intelligence about customers and company operations with employees, suppliers, and business partners. High-speed broadband is a prerequisite for the successful diffusion of e-business services, facilitating new ways of customer-supplier interaction, reduced transaction costs, and increased operational efficiency.

Broadband speed can make or break a business (Oppong, 2017). A recent study determined that Amazon might lose 1.6 billion in sales from a one-second delay in page loading time. The speed of a firm's internet service impacts how quickly employees have access to cloud apps like email, employee collaboration tools, and Customer Relationship Management apps. A slow connection not only damages the overall customer experience, but it also lowers overall company productivity. Companies use virtual private networks (VPNs), Voice over IP, video services and web conferencing tools that require more bandwidth. Cloud computing results in constant uploading and downloading of content, and access to cloud-based storage solutions becomes much more efficient with a faster broadband connection. According to the 2018 State of the Cloud Survey, 96 percent of organizations use the cloud. Low bandwidth networks require extra hardware to cache and backup files and data resulting in a lot of duplication of work at multiple locations. Firms with more sites/locations, stand to benefit more from cloud-based services and experience greater savings.

Gains in productivity have long been touted as a key benefit of advanced technology (Stiroh, 2001). The attendant efficiency gains stemming from enhanced productivity comes from savings in personnel and time, streamlined and automated process flows, fewer errors, economies of scale and lower processing costs per unit (Oliner and Sichel, 2000). Mack and Faggian (2013) conclude that the ability of these time-shrinking technologies to facilitate the finding, sharing, and storing of information, causing organizational innovations, has been due to the increased Internet connection speeds brought about by the development of high-speed broadband.

Tyson (2013) reports that a study commissioned by Sandisk found that in the U.S. the loss of productivity due to slow upload/download of digital content amounted to 4.9 days per employee per year. Gillman (2015) further explains how slow internet connections can cost time and money: "*If you or your employees spend half of each day online doing research, accessing systems or dealing with customers and vendors, that amounts to 4 hours per day. If 5 percent of that time is wasted due to slowness, over a year's time that's 50 hours per employee. If 10 percent is wasted, it's 100 hours per year per employee.*" Considering that 94 percent of jobholders are Internet users, these savings could be quite substantial.

We use a bandwidth calculator from West Central Telephone Association to gather some rough estimates of the time savings from greater bandwidth. The calculator captures download times for four files of different sizes, i.e. 12 MB, 200 MB, 12 GB and 40 GB, using different bandwidths as shown in **Table 5.1**.

Table 5.1 Download Speed by Bandwidth and File Size				
	Panel A. Time to download (seconds)			
File Size → Bandwidth (Mbps) ↓	12 Songs (12 MB)	100 Photos (200 MB)	HD Movie (12 GB)	Video Game (40 GB)
10	35.23	160.77	10,370.92	34,359.74
25	14.09	67.11	4,123.17	13,743.90
60	5.87	27.96	1,717.99	5,736.62
100	3.52	16.78	1,030.79	3,435.97
250	1.41	6.71	412.32	1,374.39
1000	0.35	1.68	103.08	343.60
Panel B. Time Savings in Minutes				
100 v 25	0.1762	0.8388	51.5397	171.7988
250 v 25	0.2113	1.0067	61.8475	206.1585
1000 v 25	0.2290	1.0905	67.0015	223.3383
1000 v 100	0.0528	0.2517	15.4618	51.5395
Panel C. Dollar Savings Per Employee Per Day†				
100 v 25	0.28	1.34	82.21	274.02
250 v 25	0.34	1.61	98.65	328.82
1000 v 25	0.37	1.74	106.87	356.22
1000 v 100	0.08	0.40	24.66	82.21
1000 v 250	0.03	0.13	8.22	27.40
Note: Speed test available at: https://www.wcta.net/speed-demo/ †Assumption: Five similar projects performed per day.				

The experiments yield interesting results. At the outset, note that 25 Mbps is the FCC's current benchmark for broadband. We consider "high-speed" broadband to be 100+ Mbps. Panel A of **Table 5.1** shows the actual download times of various files at different internet speeds. Panel B shows the relative time saved when using different bandwidths. For a 200 MB file, the difference between 100 Mbps and 25 Mbps connections is relatively small (0.84 minutes); however, when the file size increases to 12 GB (i.e. 60 files of 200 MB each), the time savings jumps sharply to 51.5 minutes. Likewise, a gigabit speed connection saves 15.5 minutes relative to a 100 Mbps connection for a 12 GB file. **Fig. 5.1** shows the dramatic difference that bandwidth makes as file size increases.

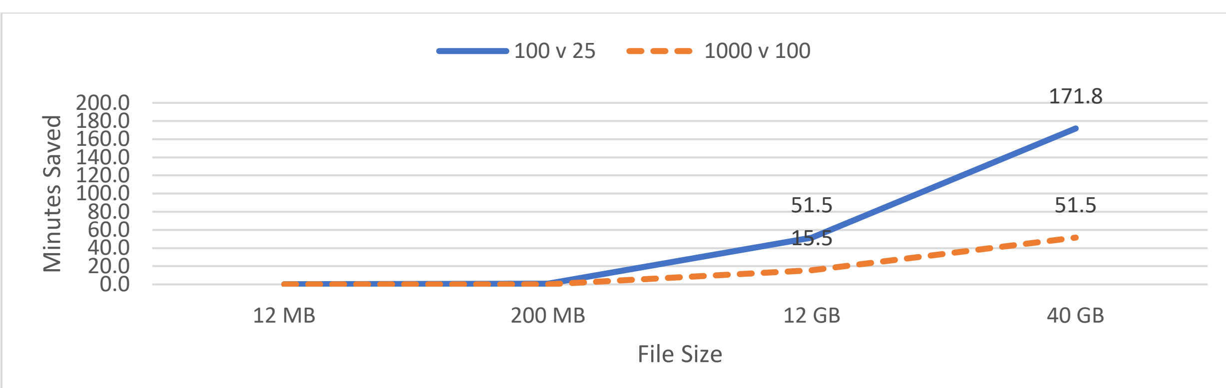

Fig. 5.1 Time Savings with Bandwidth

In Panel C of **Table 5.1**, we quantify the benefit of high bandwidths based on the assumption that a typical workday involves five iterations of these tasks per employee. At a median wage rate of $19.14/hour, we find that going from a 25 Mbps connection to a 100 Mbps connection saves $82.21 per employee per day for projects involving 12 GB files. The savings rise to $106.87 per employee per day with a gig connection. When one considers that much work nowadays involves both downloading *and* uploading, this benefit is likely greatest for fiber-delivered symmetrical speed broadband.

Fig. 5.2 shows that as the file size increases, the dollar cost savings from greater bandwidth increases dramatically. For instance, when working with large files (40+ GB), the cost savings can be as much as $356 per employee per day when upgrading from a 25 Mbps connection to a gig connection. Even upgrading from 250 Mbps to a gig results in a cost saving of $27 per employee per day. These findings point to nonlinear, and possibly exponential, benefits of greater bandwidth.

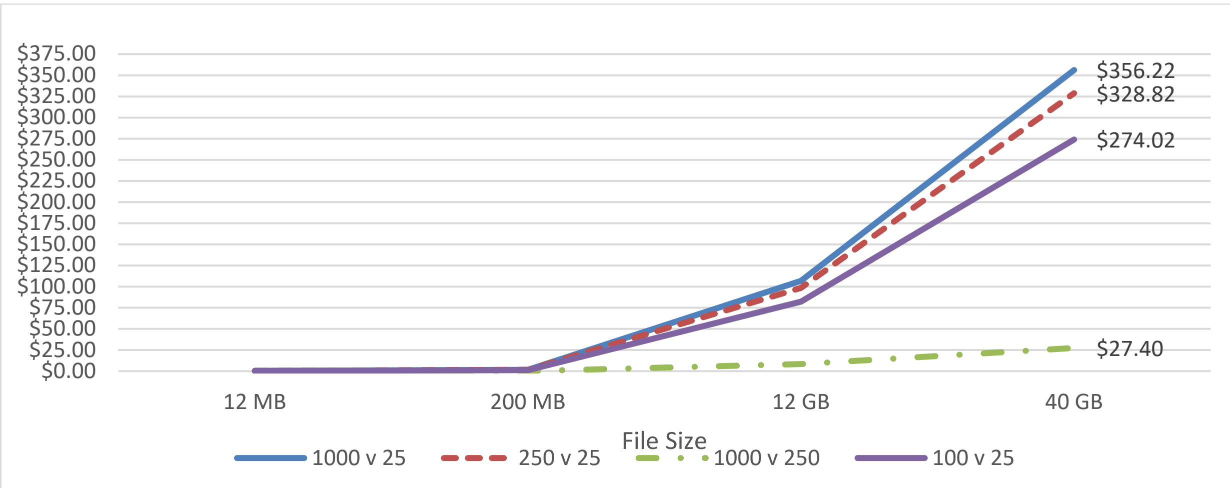

Fig. 5.2 Cost Savings from Bandwidth

Besides the benefits that come directly from deploying and using broadband services, communities that have advanced broadband services may have a competitive edge in attracting and retaining businesses. That edge can become a significant competitive factor between businesses, as well as serve as an important aspect of economic development (Pociask, 2005). As previously noted, the evidence from Hamilton County is supportive of this notion. This simple experiment also allows us to quantify some aspects of the digital divide. Communities with slower broadband connections bear a significant economic cost in addition to losing productivity.

Case Study 8: FreightWaves

Headquartered in Chattanooga, FreightWaves, a data and content forum, provides freight logistics and intelligence. It partners with the largest data providers in the freight marketplace, aggregating hundreds of sources and billions of individual data points to model near-time changes and impacts to the freight market, thereby gaining an understanding of how weather, economic activity, technology, and regulations change the freight markets. It prepares market indices, geo heat-maps, and barometers that map the freight market, helping participants understand how the market will impact them.

Craig Fuller is the CEO and founder of FreightWaves. Born and raised in Chattanooga, Fuller grew up in a family passionate about trucking; his father started US Xpress in Chattanooga in 1985. "The original idea was to create a futures market based on trucking …," Fuller said in an interview in March 2019 (Roe, 2019). "*But what we realized as we went to market is [that] in order to create a liquid futures market there has to be a news business that really talks about what's happening. There has to be data that really serves that market and that's what we went out and have built.*" The freight futures product went live April 1, 2019 on the Nodal Exchange, a part of the EEX group.

Today, Freightwaves provides the fastest view of transportation and logistics market activity. The company is also the premier source for media and market analytics in the global freight industry. Fuller describes his company as "the Bloomberg of freight". He also calls Chattanooga "the Silicon Valley of freight", the best location for freight and logistics operations.

FreightWaves is near the top of the Crunchbase rankings of startups, and ranked in the 95th percentile for growth by Pitchbook. It won Steve Case's Rise of the Rest Competition, was named FIA Innovator of the Year, and was called a CNBC Upstart 100. In July 2020, Freightwaves secured another $37 million in investment, vaulting it into the top 10 in venture capital raised in Tennessee. FreightWaves grew its top-line revenues by 50 percent in the first part of 2020 despite the coronavirus pandemic. The SONAR dashboard and its media business have each grown more than 250 percent in the first half of 2020 (Pare, 2020).

The firm utilizes the commercial gigabit service from EPB for a few hundred dollars a month, according to Daniel Pickett, CFA, Chief Data Scientist at Freightwaves. He points out the national attention and awards help the firm recruit top high-tech talent. In the Chattanooga office which employs about 100 people, the need for bandwidth is paramount. "*[For] 100 employees working remotely, VPN, video/conferencing, and file sharing is completely seamless*." The size of geospatial files often exceeds 10 GB each, and they are shared between teammates, local, and cloud vendors. The active use of cloud infrastructure, along with video streaming for the news outlet makes reliable and fast internet connectivity critical. "*The media side is streaming HD video that is recorded on-site, so there is almost constantly 1 GB upstream feed from our office. … Being able to do [all] this reliably and in a few seconds saves us considerable time*."

Additionally, the sales force makes a dozen or more sales video calls with demo screen sharing, all of which requires bandwidth. During the COVID-19 pandemic, the bandwidth has saved travel costs in airfare and hotels required for 8-10 sales demos each day

As another example of how high-speed broadband impacts business productivity, consider the following example of the Tennessee Valley Federal Credit Union (TVFCU).

Case Study 9: Banking – "Beyond Broadband"

Nick Townsend is the Virtualization Engineer at the Tennessee Valley Federal Credit Union (TVFCU). Born and raised in Bradley county TN, where there is no fiber infrastructure, Townsend feels that "*[Since 2010] EPB has knocked it out of the park*." In 2016, he recommended that the credit union switch to EPB for internet and network services. He built out the new network and has not looked back.

TVFCU, the largest federal credit union between Knoxville and Atlanta, has net assets of over $1.5 billion. With 400 FTE plus some part time employees, TVFCU serves over 150,000 members through a network of 23 branches in the Tennessee Valley. TVFCU was the first credit union to use an interactive teller machine (ITM) in addition to regular ATMs. An ITM allows users to have real time streaming consultations with bank staff from 7AM to 7PM Monday through Saturday, in addition to conducting regular financial transactions.

These ITMs are equipped to handle 5-10 MB of activity per unit. TVFCU's capacity allows for 63 simultaneous sessions of peak demand. With the onset of the COVID-19 pandemic, the credit union has plans to expand usage of ITMs significantly. During the pandemic, ITM volume has jumped 600 percent.

Townsend believes their commercial point-to-point mesh network generates redundant capacity for the credit union and allows for seamless, uninterrupted service to their members. The bandwidth is especially useful for data security and disaster recovery services, in addition to the various banking transactions such as wire transfers and check printing. Additionally, the ITMs require symmetric speed. He believes the fiber optic infrastructure has been a game-changer.

Townsend likes to contrast broadband with fiber optics. He considers the latter to be "beyond broadband" because of the reliability, security and scalability of the technology. He says that compared to even ten years ago, if the technology saved 2 minutes per employee-report per branch, that would translate to roughly an hour and a half per branch per day. Extending his analogy to the 23 branches, TVFCU is saving roughly 34 hours per day with high speed broadband. Using the median hourly wage for financial specialists in the U.S. (i.e. $34.59) as a rough proxy for the value of this time saved, we find that this high-speed connection is worth at least $553,440 per year to TVFCU.

Efficiency gains and cost savings

We estimate the value of high-speed broadband on Hamilton County businesses in terms of productivity gains, i.e. time and cost savings, for employees that belong to knowledge/high-tech industries, which we proxy by occupations that can be worked from home based on Dingel and Neiman (2020).

We assume that 4.9 workdays (39.4 hours) per employee per year are saved due to high-speed internet connectivity based on the Sandisk study referenced earlier as well as ongoing research at UTC. We then adjust the total number of employees for those belonging to high-tech firms that take the fiber data service from EPB as seen in the formula below. We then calculate the savings based on the median hourly wage rate from the BLS as seen in **Table 5.2**. [28]

Annual Efficiency Cost Savings = Employees in high-tech firms that take the fiber service x (39.4 hours saved per employee per year x Median hourly wage rate in TN)

This approach enables us to evaluate the value of the fiber optic infrastructure to businesses in the County. Over a ten-year period from 2011-2020, we estimate that high-speed broadband resulted in business cost savings from greater efficiency (reduced time wastage) in an amount of $74.3 million. [29]

[28] We use Tennessee median hourly wages as a proxy for Hamilton County wages.
[29] This estimate of County business efficiency in Table 5.2 is likely understated because we only capture the value to customers of EPB because this data is publicly available and is directly related to the fiber infrastructure. Businesses taking high-speed internet service from other providers are not included in this estimate.

Table 5.2 Business Efficiency Cost Savings					
	All Employees in Hamilton County	Employees in knowledge sector/high tech jobs	Commercial take rate of fiber data service	Median hourly wage rate in TN	Annual Efficiency cost savings from high-speed fiber internet
2011	156,845	49,936	7.3%	$14.56	$2,091,190
2012	159,052	50,639	11.4%	$14.59	$3,318,469
2013	160,673	51,155	15.9%	$14.90	$4,774,906
2014	160,737	51,175	19.3%	$15.02	$5,844,961
2015	166,245	52,929	22.2%	$15.30	$7,083,233
2016	169,785	54,056	24.9%	$15.77	$8,363,130
2017	173,163	55,131	26.4%	$15.77	$9,043,348
2018	177,575	56,536	28.4%	$17.55	$11,102,372
2019	180,790	57,559	29.1%	$17.03	$11,238,816
2020	181,163†	57,646	29.6%	$17.03†	$11,449,185
Total					$74,309,609
Source: Author calculations. †Estimate. Assumption: 39.4 hours per employee per year are saved with high-speed broadband. Employee count from the BLS. Wage data from EPI State of Working America.					

CHAPTER 6. HOUSEHOLD EFFECTS

The internet impacts nearly every aspect of American life. It has revolutionized how we communicate, learn, share information, watch TV, eat, shop, and consume news and other media. It has changed how we cook, how we read, how we do business, how we bank, and how we complain (Lisa (2019). Consider the following statistics:

- The Pew Research Center reports that 81 percent of Americans say they are online either constantly or several times a day.
- Cisco's Annual Internet Report (2019) predicts that 92 percent of people in North America will be using the internet and each person will have 13.4 networked devices and connections associated with them by 2023.
- The Internet of things (IoT), from light bulbs and smoke detectors to deadbolt locks and thermostats, reaches into every corner of the American home and office. According to a 2017 McKinsey Report, 127 former dumb devices are enlightened every second with internet connectivity.
- According to a Statista report, Americans are projected to buy over $700 billion worth of goods online by 2022.
- A study from the Food Marketing Institute conducted by Nielsen shows that by 2025, internet-based grocery sales are expected to break the trillion dollar mark and account for 20 percent of the total grocery market.
- The Department of Education's National Center for Education Statistics reports that more than 3 million distance learners pursue their college education completely online (pre-COVID-19). Another 3.55 million take at least some online courses.

6.1 Consumer Surplus

Following Lobo (2015), our approach to measuring the value of the fiber infrastructure is primarily based on the idea that high-speed broadband is essential infrastructure similar to good roads and bridges. As previously mentioned, we consider work done in measuring the economic impact of the internet as a reference point because high-speed broadband helps access the internet. The measurement is difficult because so much of the impact of the internet has no price, i.e. has non-monetary benefits. Brynjolfsson et al. (2018) argue that GDP and derived metrics such as productivity, while central to our understanding of economic well-being, are inadequate when considering digital goods and goods with no observable market prices. Changes in consumer surplus, on the other hand, provide a superior, and more direct, measure of changes in well-being in such cases. In practice, consumer surplus, i.e. the difference between the consumers' willingness to pay for a good and the amount that they actually pay, has been difficult to quantify.

Brynjolfsson et al. (2018) using massive online choice experiments found that digital goods have created large gains in well-being that are not reflected in conventional measures of GDP and productivity. Their measures of the annual consumer surplus in 2017 of various, typical internet activities are as follows: Search engines: $17,530; Email: $8,414; Maps: $3,648; Video: $1,173; E-commerce: $842; Social media: $322; Messaging: $155; Music: $168. In other words, the average person gains a value equivalent to approximately $32,000 per year from the free services on the internet. Hooton (2019) suggests that 25 percent of this consumer surplus can be attributed to non-commercial, personal use.

Previous work on measuring consumer surplus related to high-speed broadband include Orszag, Dutz and Willig (2009) who found that U.S. households' demand for broadband was roughly $32 billion higher than what they actually paid in 2008. This broadband consumer surplus represented a 58 percent increase from 2005, when broadband connectivity in the Untied States generated an estimated consumer surplus of around $20 billion. Breaking down consumer willingness to pay for broadband services revealed that younger users and users with a college education were willing to pay more than older users and users without a college degree.

Rosston, Savage and Waldman (2010) showed that reliability and speed were important characteristics of Internet service. The representative household was willing to pay about $20 per month for more reliable service and $45-48 for an increase in speed. Willingness-to-pay (WTP) for speed increased with education, income and online experience, and decreased with age. Rural households valued connection speed by about $3 more per month than urban households. Households were also willing to pay an additional $6 so that their Internet service provided the ability to designate downloads as high-priority, about $4 for the ability to interact with health specialists online, about $3 for the ability to download and view full-length movies, and about $5 for the ability to place free phone calls over the Internet and see the person being called.

Using these results, they calculated that a representative household would be willing to pay about $59 per month for a less reliable Internet service with fast speed ("Basic"), about $85 for a reliable Internet service with fast speed and the priority feature ("Premium"), and about $98 for a reliable Internet service with fast speed plus all other activities ("Premium Plus"). An improvement to very fast service added about $3 per month to these estimates (Lobo, 2015).

Chen, Jeon and Kim (2014) estimated consumer surplus from the time saved using the internet. They found that on average, it took participants seven minutes to answer some survey questions using a search engine, and 22 minutes using the University of Michigan's library. Varian (2013) calculated that those savings worked out to 3.75 minutes per day for the typical user. Assigning that time a value of $22 per hour (the average wage in America), he estimated search generates $1.37 of consumer surplus per day per user, $500 annually, or $65 billion-$150 billion nationally. [30]

Yet another way to measure consumer surplus is to assign a value to the leisure time spent on the web. Brynjolfsson and Oh (2012) noted that between 2002 and 2011, the amount of leisure time Americans spent on the internet rose from 3 to 5.8 hours per week. The authors concluded that in so far as consumers must have valued their time on the internet more than the alternatives, this increase must reflect a growing consumer surplus from the internet, which they valued at $564 billion in 2011, or $2,600 per user. Had this growth in surplus been included in GDP, it would have raised economic growth since 2002 by 0.39 percentage points on average.

Household Consumer Surplus in Hamilton County

We use household consumer surplus as a proxy for the additional non-monetary benefits of high-speed internet access. In particular, we use it as a gauge of hard-to-measure benefits from "always on" service with few outages such as the convenience of shopping from home or reading an e-

[30] http://www.economist.com/news/finance-and-economics/21573091-how-quantify-gains-internet-has-brought-consumers-net-benefits

book or viewing a streaming video or gaming. The combination of speed and availability makes home broadband connectivity an extraordinarily powerful and flexible tool that is already widely used for entertainment, work and job searches, news, health care, shopping, personal finances, social networking, travel, education and interactions with government. Internet banking, along with location-based services and time-shifted TV viewing, are among the top three fastest growing trends in online activities.[31]

To calculate the consumer surplus of the fiber-delivered high-speed broadband in Hamilton County, we use two approaches as in Lobo (2015):

1. Willingness-to-pay: Rosston et al., 2010
2. Time savings from search: Varian, 2014

<u>Approach 1: Willingness-to-pay</u>
Here we use estimates from Rosston et al., who find that a representative household would be willing to pay $98 per month for a reliable Internet service with fast speed plus all other activities ("Premium Plus") plus an additional $3 per month for very fast service (for which 100 Mbps or higher would qualify). The consumer surplus would be measured relative to the current price for high speed broadband in Hamilton County. Since EPB offers two service levels, 300 Mbps and 1000 Mbps, at $57.99 and $67.99, we use a take rate-weighted average of the two service prices, i.e. $59.91.[32] The monthly consumer surplus is $40.95 times the number of persons in households taking EPB's high-speed broadband.

<u>Approach 2: Time savings from search</u>
The second approach is based on Varian's measure of time saved from using the internet. Based on a median hourly wage of $17.03, we estimate that the savings amounted to $1.06 per user per day or $388 per user per year.

In our calculations, we proxy for the number of users (over 5 years of age) with the number of households taking high-speed broadband in Hamilton County, adjusted for the average size of the household as indicated by the Census Bureau. **Table 6.1** presents the consumer surplus estimates.

Table 6.1 Consumer Surplus in Hamilton County

Approach	Consumer Surplus per month	Users = Fiber Households x size	Annual Consumer Surplus
Rosston et al. (2010)	$40.95	119,044 x 2.46 = 275,793	$143,921,585
Varian (2014)	$32.37		$113,770,626
Average			$128,846,105
Notes: Fiber residential customers as of April 2020.			

Our estimates suggest that consumer surplus related to high-speed internet amounts to $128.8 million on average. [33] As previously mentioned, we think of this surplus as a proxy for incremental

[31] http://www.go-gulf.com/blog/online-time/
[32] Note that the third service level (10 gig) was recently introduced and is yet to gain traction in the residential market.
[33] This estimate appears to be quite small relative to our calculations based on Brynjolfsson et al. (2018). For that calculation, we consider all digital goods except e-commerce for which the authors provide estimates, and adjust for

non-monetary benefits experienced by residential customers from high speed internet access.

6.2 Residential Savings

The fiber optics division at EPB has helped reduce operating and maintenance (O&M) costs while also generating access fee revenues for the electric division. In **Table 6.2**, we see that the O&M cost savings amounted to $183 million over the period 2011-2020. Access fees and rents paid by the fiber optics division contributed $135 million to the electric division. The fiber optics division has been profitable since 2012. These divisional profits amounted to $141 million for the period from 2011-2020.

Table 6.2 Electric System Cost Savings Due to Fiber Optics Division

	Fiber Optics O&M Allocation ($000)	**Fiber Optics Access Fees & Rent Paid ($000)**	**Fiber Optics Net Profit ($000)**
2011	$6,428	$5,374	-$1,835
2012	$8,525	$8,629	$4,086
2013	$10,551	$9,210	$5,550
2014	$11,567	$11,430	$11,401
2015	$15,586	$13,982	$11,676
2016	$17,849	$14,384	$18,425
2017	$23,232	$15,302	$22,019
2018	$27,047	$15,631	$24,192
2019	$30,423	$19,118	$21,202
2020	$31,811	$21,957	$24,460†
Total	$183,019	$135,017	$141,176

Source: EPB. † Estimate.

The cost savings and cash generated by the fiber optics division (over $318 million in ten years) has resulted in lower internet and power bills for residents, the build-up of cash reserves to deal with contingencies and plant replacement and maintenance, deferment of electric rate hikes, and avoided costly capital market transactions (e.g. bond issues). Fitch, a leading national credit rating agency, reaffirmed its AA+ rating of EPB in December 2019. The agency cited, "*very strong revenue defensibility, very low operating risk, and a very strong financial profile*."

Fig. 6.1 shows that over the 2011-2019 period, residential customers in Hamilton County have paid 16 percent less per kWh than the national average.

a) 25% of personal use and b) persons over 5 years of age in households that take the fiber data service. We estimate consumer surplus of the internet for Hamilton County to be $1.47 billion. However, we do not use this estimate in our final calculations because of the arbitrariness of the digital goods considered.

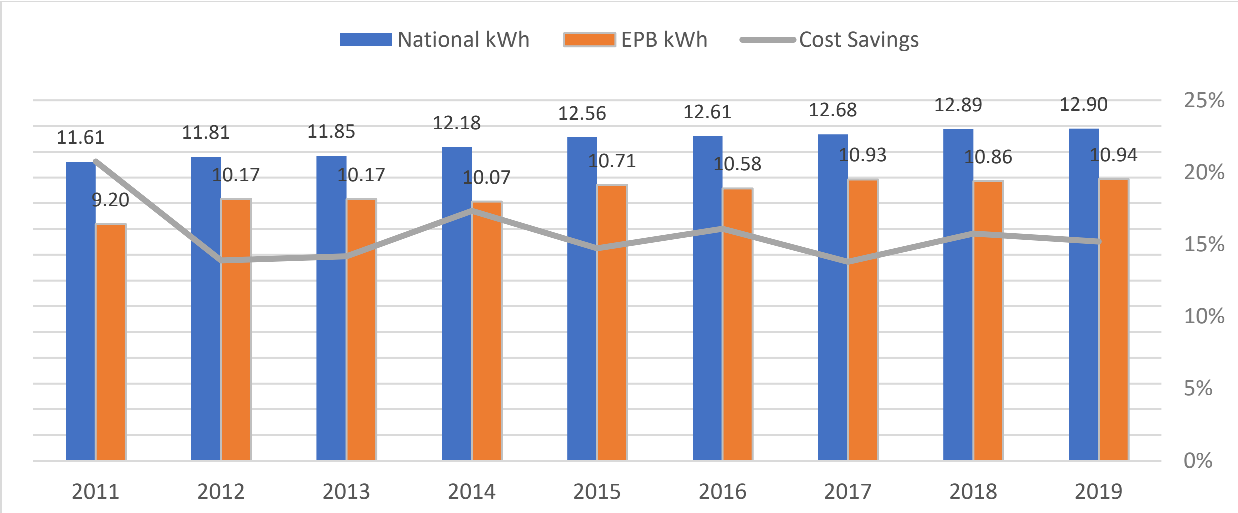

Fig. 6.1 Average cost per residential kWh (cents)

In **Table 6.3**, we show the size of community savings due to the fiber optic division. We calculate how much higher the revenues of the electric division would need to be to maintain the same level of net income reported, *absent access fee revenues and cost savings generated by the fiber optic division*. To make this calculation, we take the ratio of fiber optic access fees and O&M allocations (from **Table 6.2**) to the electric division revenues and find that, on average, electric rates would have had to rise 5.65 percent each year, roughly $7.74 per month or $93 per household per year, for EPB to generate the same level of net income without the cost savings and revenues provided by the fiber optics division. Based on average monthly residential electric bills in Hamilton County, we calculate this benefit to the community to be $144.9 million in residential cost savings, i.e. roughly $930 per household, over the period 2011-2020.

Table 6.3. Community Cost Savings Due to Fiber Optics Division

	Fiber Transfers to Electric ($000)	Annual Electric Revenues ($000)	Fiber Transfers as % of Electric Revenues	Average Monthly Residential Electric Bill	Number of Residential Meters	Annual Community Savings
2011	$11,802	$548,766	2.15%	$130.00	148,033	$4,966,516
2012	$17,154	$558,125	3.07%	$130.72	148,817	$7,174,799
2013	$19,761	$552,627	3.58%	$131.78	149,886	$8,475,588
2014	$22,997	$564,623	4.07%	$131.69	150,961	$9,716,519
2015	$29,568	$553,139	5.35%	$132.19	152,503	$12,931,397
2016	$32,233	$549,421	5.87%	$136.13	154,273	$14,784,971
2017	$38,534	$567,035	6.80%	$140.76	155,745	$17,877,613
2018	$42,678	$567,058	7.53%	$140.11	157,547	$19,935,978
2019	$49,541	$570,576	8.68%	$140.97	159,504	$23,427,761
2020†	$53,768	$572,259	9.40%	$139.32	163,020	$25,607,481
Total	$318,036		5.65%#			$144,898,624

Source: EPB and author calculations. Fiber transfers to the Electric division are access fees/rents and O&M allocations. † Electric revenues for 2020 are estimated. # average.

CHAPTER 7. COMMUNITY EFFECTS

7.1 Healthcare

"Given that broadband access intersects with so many …social determinants of health, several national organizations have recently characterized broadband access as a "super-determinant" of health."

- Bauerly, McCord, Hulkower (The Journal of Law, Medicine & Ethics, 2019)[34]

7.1.1 Telehealth

As COVID-19 shines a spotlight on remote communication and social distancing, the value of fast and reliable broadband has become particularly important in the delivery of healthcare and the management of public health. Telehealth bridges the gap between people, physicians and health systems, enabling everyone, especially symptomatic patients, to stay at home and communicate with physicians through virtual channels, helping to reduce the spread of the virus to mass populations and the medical staff on the frontlines (Siwicki, 2020).

Even as the nation's health care workforce combats the spread and lethality of COVID-19, a report from the Association of American Medical Colleges (AAMC) projects that the United States will face a shortage of between 54,100 and 139,000 physicians by 2033 (Boyle, 2020). The study projects a shortage of between 9,300 and 17,800 medical specialists; 17,100 and 28,700 surgical specialists; and 17,100 and 41,900 other specialists, including pathologists, neurologists, radiologists, and psychiatrists. Further, if underserved populations had health care use patterns like populations with fewer access barriers, demand could rise by an additional 74,100 to 145,500 physicians, With the senior population set to double by 2050, such a shortage could create significant problems for the healthcare system. The biggest issues patients will face in light of staffing shortages are spotty care, longer waits for primary care physicians, and medical errors.[35] Part of a multi-pronged strategy to combat this shortage includes better use of technology, especially in telehealth, to consistently meet the demand for services.

Bauerly et al. (2019) point out that internet connectivity, particularly access to broadband, is playing an increasingly important role in healthcare and public health. To the extent that broadband access affects socioeconomic factors such as education and employment, both of which have important implications for health outcomes, they characterize broadband access as a "super-determinant" of health. Global Market Insights estimates that global telehealth will be a $176 billion industry by 2026. This 19.2 percent compound annual growth rate (CAGR) will be largely fueled by worldwide telecommunication network developments, market opportunities in rural areas or those without easy access to healthcare services, and the continuing integration of healthcare and IT market sectors.

Broadband-enabled telehealth encompasses real-time remote patient consultations; remote monitoring of patients' vital signs and conditions; the storing and forwarding of critical health

[34] "Broadband Access as a Public Health Issue: The Role of Law in Expanding Broadband Access and Connecting Underserved Communities for Better Health Outcomes," The Journal of Law, Medicine & Ethics, July 12, 2019.
[35] http://www.broadbandexpanded.com/policymakerfiles/telemedicine/Telemedicine_Stats&Data.pdf

information for analysis and diagnosis (e.g. MRI results and electronic health records); the provision of specialized services over long distances (e.g. teledentistry, telepharmacy, telepsychiatry, and mHealth); the wide availability of health information to patients and caregivers, and access especially to medically underserved populations ("Telehealth and Telemedicine"). Chang, Savage and Waldman (2017) determine that the average household was willing to pay about $52.68 more per year for internet service (relative to what they were paying) that gave them the ability to receive remote diagnosis, treatment, monitoring and consultations.

The CDC points out that telehealth has the potential to save billions of dollars in healthcare expenditures. Effective telehealth, however, is only possible with high-speed and reliable broadband connectivity. The U.S. Centers for Medicaid & Medicare Services expanded coverage in March 2020 for telehealth services during the COVID-19 crisis to include evaluation and management visits (common office visits), mental health counseling and preventive health screenings.

New data from FAIR Health's Monthly Telehealth Regional Tracker, a free service that uses a repository of over 31 billion private health care claim records, shows that in April 2020, when the pandemic was escalating rapidly in the United States, telehealth claim lines increased over 8,000 percent nationally, from 0.15 percent of medical claim lines in April 2019 to 13 percent in April 2020. [36] In the northeast, where the pandemic initially was most severe at the time, claim lines jumped over 26,000 percent from 0.07 percent in April 2019 to 19.69 percent in April 2020 (Gelburd, 2020). From March 16 to April 14, BlueCross BlueShield of Tennessee processed 1,800 percent more claims compared to the same period in 2019 (i.e. 71,000 telehealth claims v 3,900 claims) in the Chattanooga area (Crisman, 2020).

Hamilton County Effects

In Good Health is a Chattanooga-based family medical practice that took part in a pilot test for Docity telehealth products and services conducted by EPB. "*Our patients who are under 40 were the most enthusiastic, especially if they have young children*," Dr. Laurie Davis, principal of the practice, told *Government Technology* (Settles, 2018), well before the onset of COVID-19. "*Parents quickly understand that hours spent in the waiting room full of other sick kids can be painful, and a video consult is just like being in the room with the doctor*." Davis' office uses EPB-provided broadband.

Case Study 10: CHI Memorial Hospital

Paul Marsh is the IT Director for CHI Memorial Hospital in Chattanooga. He is a 25-year veteran of the healthcare industry and oversees IT operations for the main campus, as well as for two other campuses in Hixson and North Georgia. These 3 hospitals serve roughly 30 nearby counties in a wide sweep from Spring City TN to Lafayette GA. Additionally, he oversees the IT needs of 50 physician clinics involving roughly 135 physicians of different specialties. The CHI group locally has roughly 575 licensed beds in addition to ER outpatient beds.

CHI's primary data center is in Richardson TX. The Chattanooga operations use two gigabit pipes to connect to this data center. The connections are provided by a mix of CenturyLink and Level 3 (parts of AT&T) and EPB. Within the

[36] A claim line is an individual service or procedure listed on an insurance claim.

Chattanooga hub and spoke infrastructure, they use two connections from AT&T and EPB to connect facilities. The physician clinics owned by CHI have minimally 100 MB circuits; several connect through a mesh VLAN.

What does Marsh look for with his technology connections? Consistent throughput, bandwidth, and quality of service metrics. He finds that the minimum requirement is 100 MB for facilities with 8 to 10 users; larger bandwidths are necessary for bigger operations, and symmetrical upload and download speed is important.

The broadband service is primarily used for delivery of applications, such as EHR and practice management, telehealth, cloud services and cyber security. Marsh plans for redundancy by operating at 30-50 percent of the available bandwidth. The highest usage time is in the morning when everyone is logging on and authentication/cyber security kicks in.

Marsh notes that physician productivity is closely linked to bandwidth because one criterion of performance is the number of patients treated. In addition to bandwidth, the speed and efficiency of the system depends on hardware (such as processors, RAM and servers) and the nature of applications being used.

Relative to 10 years ago, Marsh notes the significant pick up in speed with which medical records are accessed, analyzed and shared. As a consequence, patient care has improved. Typical metrics of health outcomes, such as patient length of stay, door-to-doc time for ER patients, door-to-needle time for stroke patients, have all declined significantly over time. Additionally, communication between ambulances and EMS staff has improved resulting in patients receiving quicker diagnoses and treatment.

Pre-COVID-19, telehealth accounted for less than one percent of all patient consultations at CHI. Such virtual visits were mostly for psych consultations, some infectious diseases, and for some specialty services and rural consultations. When COVID-19 pushed CHI to shut down all elective procedures in March 2020, the hospital was forced into the realm of telehealth. They use a special Zoom product with security features. By April 2020, some 60-70 percent of the operations of their physician clinics were engaged in virtual consultations. Since reopening to elective procedures in early June, some 40-50 percent of hospital operations remain virtual. Patients love it and physicians are more comfortable with it and are compensated adequately. Marsh believes that telehealth is here to stay - people are getting used to it and warming to its potential.

Marsh says that now more than ever, symmetric and reliable bandwidth is critical. The video component of the consultation critically depends on a solid internet connection. His system is running at about 65 percent of capacity, i.e. with plenty to spare. This facilitates a largely seamless virtual visit.

Erlanger hospital in downtown Chattanooga provides another example of how bandwidth is used in healthcare.

Case Study 11: Erlanger Baroness Hospital

Danny Stevens is the Network and Telecom Manager at Erlanger Hospital in Chattanooga, a top-10 public hospital in the U.S. He manages all the network connections/internet/telecom for the main campus as well as remote campuses in the East and North of Chattanooga, in Murphy NC and Bledsoe TN, and for 50 physician offices. Erlanger has a Level I Trauma Center, a Children's Hospital and the Southeast Regional Stroke Center. The Hospital system employs around 7,000 people including around 1,000 doctors. As a teaching institution, several hundred medical residents rotate through Erlanger every year.

Erlanger is served by two gigabit pipes of internet connectivity from EPB. Physician offices receive 100 MB connections, on average. Additionally, Erlanger uses EPB's 5 gigabit co-location service mostly to maintain business continuity in the event of some disruption. Most of their 600 servers are hosted locally for security reasons, while some are hosted in the cloud.

Stevens has been with Erlanger since 1984. Naturally, he has seen many changes in that time. As recently as 5 years ago, he says they used a 200 MB connection; 7 years ago, it was 50 MB. Today, the gigabit speed is critical and results in significant benefits to patient care. This is especially noticeable for stroke victims. Now scans are sent to the cloud where AI looks at it and moves the needle on care very quickly.

Stevens believes fiber optics has changed the way they do business. Everything is much faster and the service from EPB is not only significantly cheaper than what they paid for previously, but the low latency is especially valuable. This value is felt most noticeably by radiologists and for those using the PACS imaging services. He estimates the EPB product generates cost savings that run in the hundreds of thousands of dollars. Moreover, Stevens says the service from EPB is hard to beat. They use roughly 30 percent of their bandwidth capacity, generating plenty of redundancy.

Additionally, people can work from anywhere. The COVID-19 pandemic has resulted in all of their physician offices offering some form of telehealth service. Stevens believes some 500 more employees are working from home compared to prior to the pandemic.

A classic telemedicine example is that of Regional Obstetrical Consultants, a high-risk OBGYN practice in downtown Chattanooga.

Case Study 12: Regional Obstetrical Consultants

Regional Obstetrical Consultants (ROC), located in downtown Chattanooga, is a high-risk obstetrics practice. In 2009, with support from BCBST's Solutions for Obstetrics in Rural Counties (STORC) initiative, ROC began a telemedicine practice. They serve 11 remote sites in Tennessee and Georgia. By connecting patients to high-risk obstetrical specialists, the STORC program seeks to reduce unnecessary patient transportation and hospitalizations as well as the length of stay in neonatal intensive care units. Moreover, each teleconsultation takes about 15 minutes less than a normal 45 to 60 minute face-to-face consultation/visit, and telemedicine patients miss fewer appointments compared to in-person patients.

ROC maintains EMR, PACS and telemedicine services on their gigabit internet service provided by EPB. Backups are maintained on- and off-site and disaster recovery services are maintained using co-location services. Tele-consultations are delivered via a 10 Mbps symmetrical connection.

Each remote site has 1-2 advanced care personnel and 1-2 stenographers. The team of physicians visits the remote sites once a week. The average monthly cost of maintaining a telemedicine site (e.g. IT, rent, personnel, transportation, etc.) is $39,593. Moreover, portable equipment costs are significantly lower. A typical precision ultrasound machine costs $250,000, whereas a portable unit costs $46,925.

Data from ROC shows that over the period 2013-2020, ROC had 34,379 scheduled tele-visits, with a no-show (missed appointment) rate of less than one percent compared to 12 percent for in-person appointments at the main office.

The average distance of the telemedicine sites was 82 miles from the main office. At 50 mph, each patient would spend 3.3 hours traveling to and from an in-person visit. Further, each patient averages 6 visits/appointments over a pregnancy term. Thus, each patient would save 21.5 hours just in travel time during a pregnancy (including the savings in consultation time). At a median wage rate of $17.03 per hour and mileage rate of $0.47/mile, the total saving in travel time (i.e. wages saved) and mileage per patient amounts to $819 per pregnancy due to the virtual visits. A total of 112,128 hours were saved from ROC patients not having to drive to Chattanooga for an in-person visit. The cumulative benefit of time/wage and mileage savings from 2013 to 2020 amounts to $4.69 million.

The STORC grant runs out in June 2020, but ROC plans to continue its telemedicine efforts given the many benefits it brings to patients.

7.1.2 Medical Imaging

Case Study 13: Dr. Jim Busch, Radiologist

Dr. James M. Busch is a radiologist who moved from Boston to Chattanooga in 2004. When medical imaging transitioned to Picture Archiving and Communication System (PACS) in the early 2000s, all imaging went digital and the need for reliable and large bandwidth became critical. In Boston, he paid around $15,000 per month for a T3 connection which is 33 percent slower than a 100 Mbps connection. After moving to Chattanooga, his telco budget dropped significantly while increasing efficiency and improving the quality of medical care.

The effectiveness of emerging telehealth technology is directly tied to broadband speed. Dr. Busch has been utilizing EPB's 1 Gigabit VLAN product for both his office and his home to provide a telehealth business in the Chattanooga area which seeks to increase the quality of care, decrease emergency room wait time, and reduce hospital stays. His monthly cost for the VLAN from the imaging center to the data center is around $500. On Oct 23, 2015, Dr. Jim Busch became the first person in the world to have a 10-gigabit per second residential internet connection. He wrote software to enable his group to deliver new services, including making it easier for radiologists to read and annotate images from wherever they are (Omarzu, 2015). It is not uncommon for more than 10 radiologists to be sending multiple files simultaneously that each are 80 to 100 megabits in size. The city's gigabit network saves radiologists and medical facilities 40 hours per radiologist, which represents a sizable dollar savings. This time savings is manifest in their ability to serve more hospitals and patients, grow and to expand the business.

Moreover, the system allows for a less than 15-minute turn around per STAT exam with the average exam completed in less than an hour. In emergency situations in which every second counts, the quicker turnaround results not merely in cost cutting efficiencies but also in life saving opportunities. Traditionally, patients requiring these tests may have had to stay overnight, waiting for results. This technology makes it possible to reduce the length of hospital stays or even avoid staying in the hospital entirely, reducing payment burdens on patients and taxpayers.

Data provided by Dr. Busch shows that bandwidth consumption in the Diagnostic Radiology Consultants (DRC) group that his father co-founded, has grown significantly over the past 12 years; at a CAGR of 11.4 percent. **Fig 7.1.1** shows that by 2019, bandwidth consumption had grown to over 18,000 GB per year, with average annual data usage of 10,756 GB.

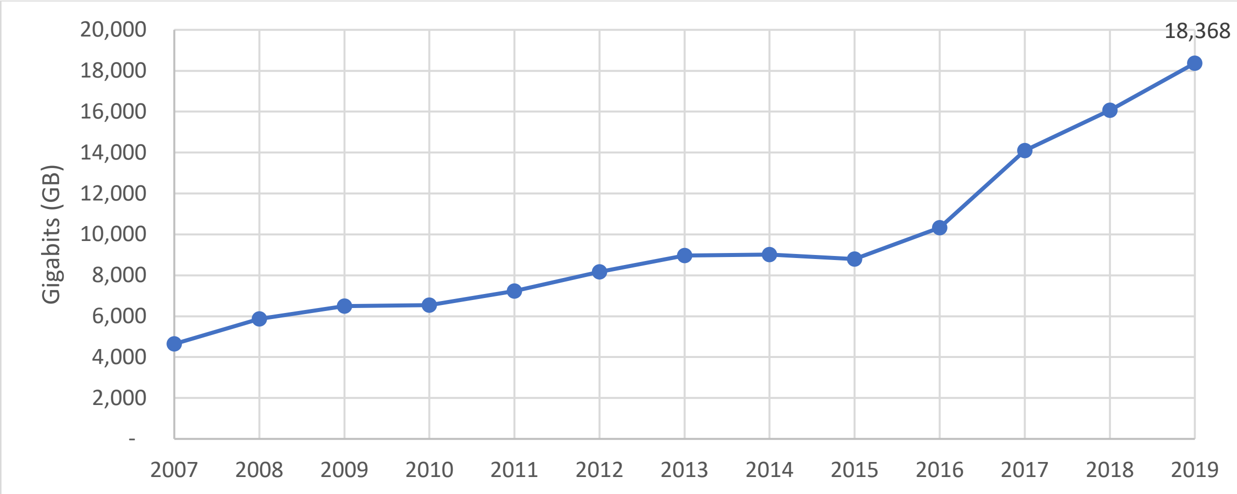

Fig. 7.1.1 Diagnostic Radiology Consultants - Data Usage (2007-2019)

Using the bandwidth calculator described in Chapter 5, we find it would take 26 hours (1.07 days) to upload and download all the files they work with using a gigabit connection, while it would take 1,027 hours (43 days) to do so using a 25 Mbps connection (see **Fig 7.1.2**).

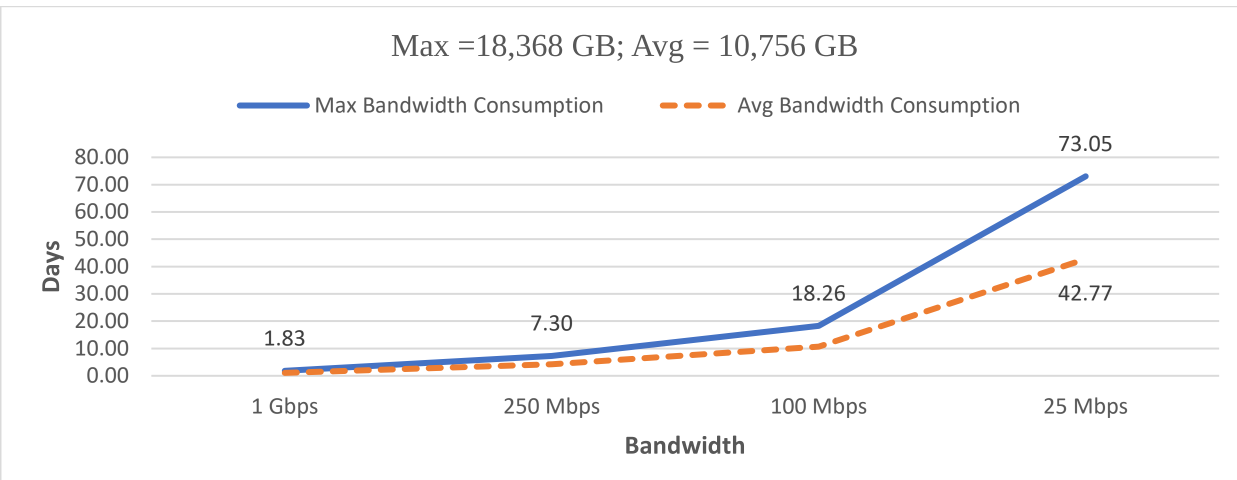

Fig. 7.1.2 Diagnostic Radiology Consultants - Days to Completion (2010-2019)

In other words, going from 25 Mbps to 1,000 Mbps (gig) service, enables DRC to boost radiologists' productivity by saving 1,001 hours per year in meeting their average bandwidth needs. At an average radiologist FTE of 9.3 over the past ten years, each radiologist is saving about 107 hours per year. This amounts to an annual savings of $178,165 for DRC at a radiologist's hourly rate of $178/hour, i.e. $1.8 million over ten years. Dr. Busch adds that the significantly lower cost of fiber broadband further boosts the savings for DRC.

Extrapolating, the DRC experience to all diagnostic imaging in Chattanooga that take the fiber service, we find that fiber broadband service added $18.2 million of value to the medical imaging community over ten years.[37]

We note that the lack of local data, especially on telehealth metrics, prevents us from adequately measuring the value of fiber broadband on healthcare. It is likely that COVID-19 will force local authorities to systematically track such metrics in the days ahead.

7.2 Telecommuting

"What might emerge is a future in which results-oriented introverts prevail while those who thrive on face-to-face interactions and office politics fumble. In the post-pandemic workplace, nerds may get their revenge." – Khazan (May 4, 2020)

Telecommuting refers to working from home (WFH) or satellite offices as opposed to commuting to a physical place of work. Research shows that telecommuting can contribute to time and cost savings as when employees share a reduced office space, use the same facilities on a rotating basis, share large files, access the corporate network from home, and reduce office space rental and parking expenses. Telecommuting can improve environmental factors by reducing cold starts, emissions, and miles traveled. Measurable benefits also stem from savings in travel time and transportation costs (Lobo, 2015).

Telecommuting has been shown to facilitate group collaborative projects (Tarallo, 2018). Additionally, firms could access a larger labor pool, and induce well-qualified people to a region, and assist persons with disabilities who are unemployed or underemployed. These and other factors contribute to reduced absenteeism, and improvements in employee retention rates, thereby reducing recruitment and training costs.

The Texas A&M Transportation Institute (TAMTI) in reiterating the benefits of telecommuting points out that traffic congestion and accidents can cost billions in wasted fuel, productivity loss and healthcare costs. U.S. residents lose an estimated 97 hours each year and waste about 3.3 billion gallons of fuel in traffic congestion (Lamb, 2019; Cooper, 2020). Traffic can also increase fossil fuel emissions, as vehicles spend more time on the road, and burn fuel less efficiently. Traffic problems also translate into delays in trucking operations, which has significant implications for other sectors of the economy. Trucking delays alone cost $20.1 billion in 2017 ("Traffic Congestion"). The CDC estimates the cost of medical care and productivity losses associated with occupant injuries and deaths from vehicle traffic crashes exceeded $75 billion in 2017. They estimate that for every person killed in a vehicle accident, eight are hospitalized and 100 are treated at emergency rooms. Reducing accidents could save up to $190 billion in related healthcare costs.

The Pew Research Center reports that generally, "knowledge workers" and people who do most of their work on computers have access to telework. Around a quarter of workers in "management, business and financial" occupations – such as corporate executives, IT managers, financial analysts, accountants and insurance underwriters – have access to telework. So do 14 percent of

[37] There are 102 VLAN fiber products/services subscribed to by the medical community in Chattanooga. We use these customers as a proxy for medical imaging that uses fiber broadband in the healthcare sector.

"professional and related" workers, such as lawyers, software designers, scientists and engineers. When viewed by industry, the Pew study shows that about a third of employers of insurance carriers (32%) can telework, followed closely by "professional and technical services" (29%), such as law firms, accounting firms, advertising agencies and consultancies. Sixteen percent of workers in the information sector have telework access (Desilver, 2020).

Hamilton County Estimates

The 2019 Urban Mobility Report put out by the TAMTI reports data through to 2017. They find for the Chattanooga MSA that the annual delay due to traffic amounted to 28 hours per commuter. They estimated that the annual congestion cost due to traffic amounted to $241 million or $599 per commuter, an uptrend relative to 2014. The annual wasted fuel per auto commuter was 13 gallons.

Roughly 165,608 workers in Hamilton County who were 16-years and older commuted to work each day in 2018, according to the U.S. Census. Of these, 82.3 percent drove alone, 8.2 percent carpooled, 1.1 percent used public transport, 2 percent walked, and 5.4 percent (or 8,874 workers) worked from home. [38] The mean commute time to work in Hamilton County TN was 21.7 minutes (0.3617 hours) one-way. This implies a round-trip travel distance of 36.2 miles each day at a speed of 50 miles per hour.

To calculate the effect of fiber optic infrastructure on telecommuting, we:

1. use the Census' estimates of the percent of the commuting work force that works from home to calculate the total number of telecommuters in the county
2. multiply the total number of telecommuters by the commercial take rate for fiber optic services in the county to estimate telecommuting facilitated by fiber infrastructure (we call them "fiber telecommuters")

We assume that WFH employees work 2.5 days a week for 52 work-weeks per year, i.e. for 130 work-days per year, based on common industry norms cited by Global Workplace Analytics.

Fig 7.2.1 shows the uptrend in telecommuting in the county, pre-COVID19.

[38] Nationwide, the 2019 Census reports 5.3 percent of workers as "working from home." By comparison, Krantz-Kentkrantz (2019), who used 2013-2017 American Time Use Survey (ATUS) data, found 20.5 percent of workers working from home in some way on an average day. The remote worker fraction in the ATUS is 11.4 percent. Upwork's "Freelancing in America Survey" reported 16.8 percent of workers report doing most or all of their work remotely, though this includes people working from co-working spaces, coffee shops, homes, etc. (Ozimek, 2020). The wide range in estimates suggests respondent uncertainty about the precise meaning of questions.

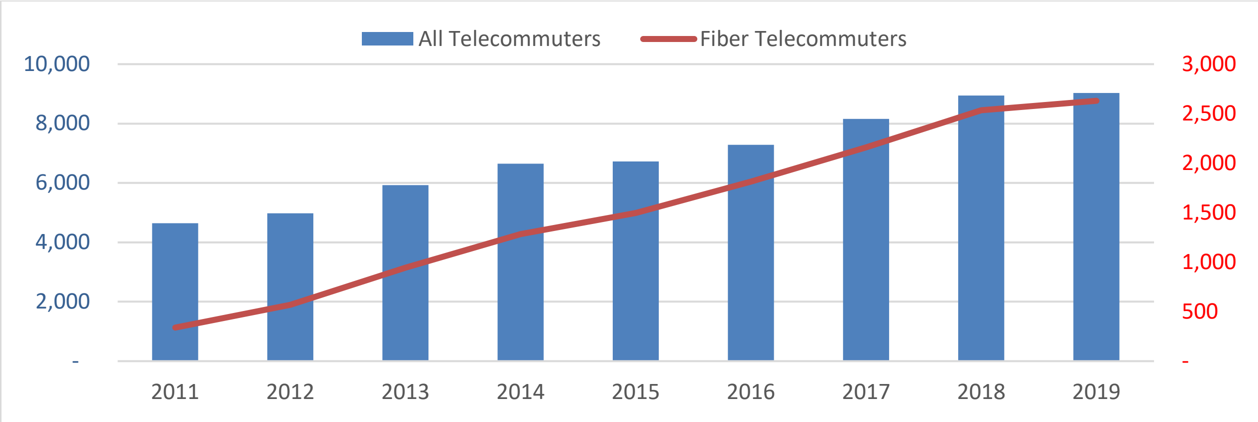

Fig. 7.2.1 Telecommuting Trends in Hamilton County

Calculations of time and cost savings are based on Crandall and Jackson (2001).[39]

- The savings in travel time can be computed as follows:
  No. of "fiber telecommuters" x Roundtrip hours/year x Half median hourly wage rate[40]

- The savings in travel cost can be computed as follows:
  No. of "fiber telecommuters" x Average roundtrip commute miles per year x Average cost per mile[41]

- Additionally, the reduction in congestion costs can be computed as follows:
  No. of "fiber telecommuters" x Annual Congestion Cost per Auto Commuter[42]

Fig 7.2.2 shows the time and cost savings associated with telecommuting. We estimate that over the nine-year period 2011-2019 pre-COVID-19, the total savings in travel time, travel costs and congestion costs amount to $65.4 million.

[39] The largest telecommute programs in Chattanooga are attached to BCBST, Unum, Cigna and EPB.
[40] A proxy for the cost of leisure. Tennessee median hourly wages used here.
[41] Based on the University of Tennessee Travel Policy.
[42] From the TAMTI Urban Mobility Report 2019. Data for Chattanooga MSA available for 2014-2017; other years were estimated. Telecommuters adjusted for those who walk to work.

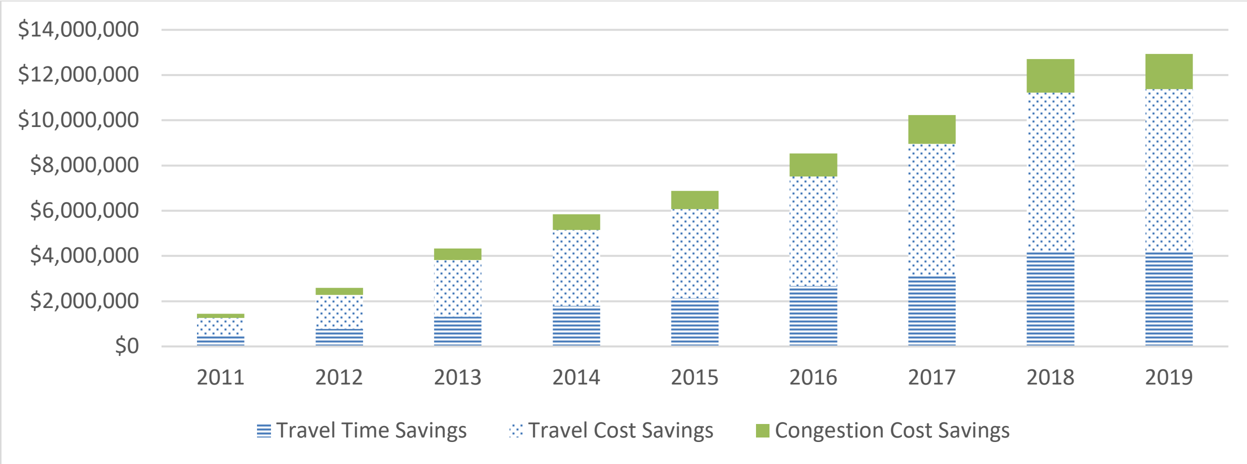

Fig. 7.2.2 Telecommute Savings in Hamilton County

COVID-19 Pandemic Adjustment

When the new coronavirus pandemic took a hold in February 2020, the U.S. went through a rapid period of locking down and working from home. A Brookings Institution study ("COVID-19") points out that the surge in teleworking begs questions regarding the ability of technologies that facilitate telework (such as video conferencing) to handle the surge in pandemic traffic. While close to a quarter of American workers teleworked to some degree prior to the pandemic, nearly 10 percent of working age adults do not have a home broadband connection, and a quarter of these workers say that services are not available or are too slow where they live. The coronavirus disruption is shining a bright spotlight on the need for fast and reliable digital connectivity.

A Pew survey in late March 2020 showed 40 percent of adults ages 18 to 64 reported they had worked from home as a result of the coronavirus outbreak. This is the same as the share of American workers who are estimated to hold jobs (such as computer programmers, economists and human resource managers) that could be teleworked (Kochhar and Passel, 2020). This finding is corroborated by Brynjolfsson et al. (2020) who found (from a survey during the first week of April 2020) that the fraction of workers who switched to working from home is about 35.2 percent. Including the 14.6 percent who were already working from home (all the time) pre-COVID-19, roughly half of the American workforce has been working from home during the pandemic.

A May 2020 RedFin survey showed about 4 in 10 survey respondents were not working remotely before the shutdowns but were able to during the shutdowns, and more than 28 percent of them said that they expected to continue to work remotely or have the option to work from home after the shutdown ends (See **Fig 7.2.3**). In Seattle, 44 percent expected to work remotely indefinitely, while 30 percent of New York City's workforce expected to do the same (Ellis, 2020).

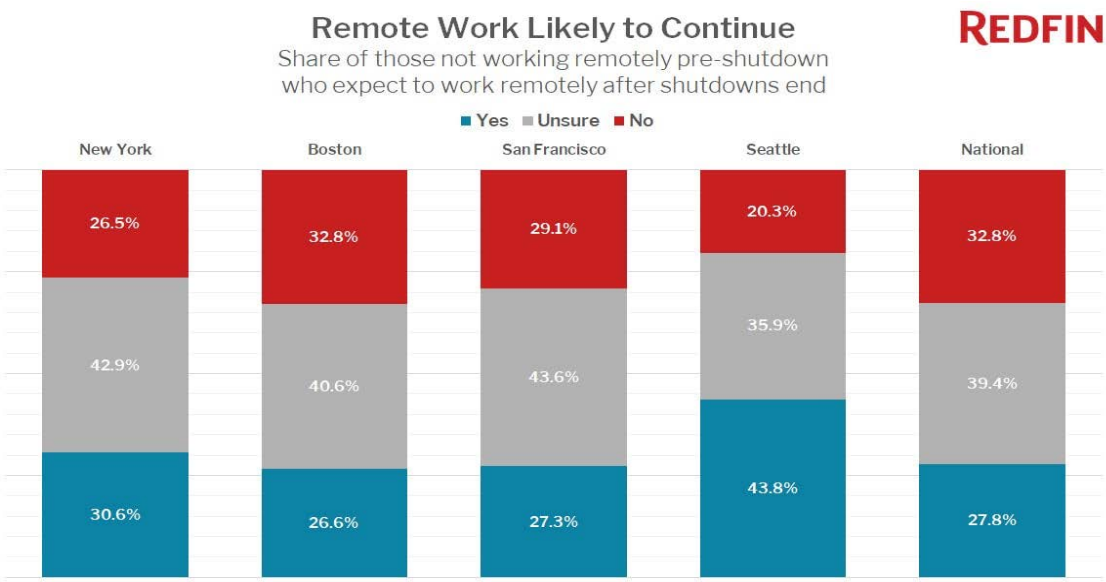

Fig. 7.2.3 Work from home survey of 4 big cities

Similar to the RedFin survey, Global Workplace Analytics estimates that 25-30 percent of the workforce will be working-from-home multiple days a week by the end of 2021 as employers and employees rethink the "where" and "how" of work. They estimate that a typical employer can save about $11,000 per year for every person who works remotely half of the time. Employees can save between $2,500 and $4,000 a year (working remotely half the time) and even more if they are able to move to a less expensive area and work remotely full time. [43] They also estimate that WFH initiatives will save U.S. employers over $30 billion dollars *a day* during the COVID-19 crisis.

In ongoing research, Dingel and Neiman (June 19, 2020) estimated that for the Chattanooga MSA, 32 percent of all jobs can be done from home. The industries best positioned for WFH are educational services, professional/scientific/technical services, management of companies and enterprises, finance and insurance, and information. The industries least well-positioned for WFH are accommodation and food services, agriculture / forestry / fishing / hunting, retail trade, construction, and transportation/warehousing.

In estimating telecommuting in Hamilton County in 2020 in the wake of COVID-19, we:

1. Calculate the number of workers in the County that could work from home, i.e. 32 percent of those employed (adjusted for industry), based on Dingel and Neiman (2020)
2. Assume that 30 percent of the workers who can work from home (i.e. calculated in (1) above) will work from home through the rest of the year based on forecasts from Global Workplace Analytics.[44]

[43] Employer savings are the result of increased productivity, lower real estate costs, reduced absenteeism and turnover, and better disaster preparedness. Employee savings are primarily due to reduced costs for travel, parking, and food. They are net of additional energy costs and home food costs.
[44] This amounts to 8.6 percent of all commuters, relative to around 5.4 percent in the previous year.

3. Adjust the number of telecommuters in (2) by the commercial take rate for fiber optic services in the county to estimate telecommuting facilitated by fiber infrastructure

Fig 7.2.4 shows the sharp increase in telecommuters in the county in 2020. We estimate close to twice as many telecommuters in 2020 compared to 2019.

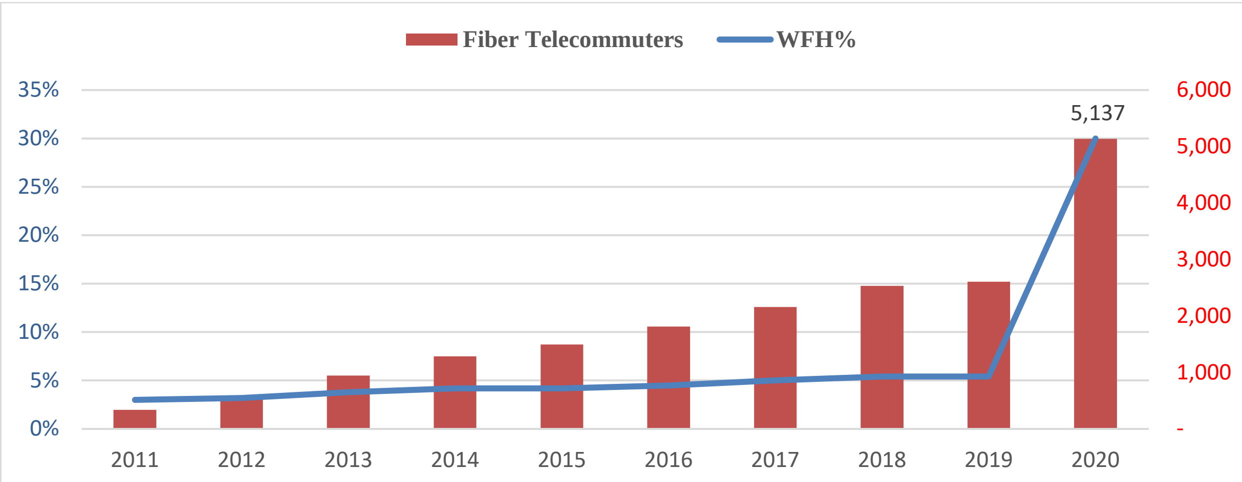

Fig. 7.2.4 COVID-19 Effects of Telecommuting in Hamilton County

Based on our assumptions, we expect $25.1 million in telecommuting savings for the county in 2020. Over the ten-year period 2011-2020, we estimate telecommuting savings of $90.6 million for Hamilton County.

7.3 Education

"The coronavirus pandemic isn't making broadband essential – it [is]exposing that it always was." – Fishbane and Tomer (2020) – Brookings Metro's COVID-19 Analysis.

The 2017 report of the U.S. Department of Education's Office of Educational Technology says it has a goal of "everywhere, all-the-time learning". Technology can be a powerful tool for transforming learning. It can help affirm and advance relationships between educators and students, reinvent our approaches to learning and collaboration, shrink long-standing equity and accessibility gaps, and adapt learning experiences to meet the needs of all learners.

Roughly six-in-ten students say they use the internet at their home to do homework every day or almost every day (Milanesi, 2020). Yet, when one talks about technology for education, one usually thinks of iPads and Chromebooks, and the various apps that students are using to learn, do homework, and take tests. In most U.S. schools, students have access to at least one computing device. But if the coronavirus crisis has made anything clear, it is that technology is an empty promise without connectivity.

Digital technologies impact all forms of education. The implications for informal learning are profound, as are the notions of 'just-in time' learning and 'found' learning, both ways of maximizing the impact of learning by ensuring it is timely and efficient. However, the integration of educational technology is largely dependent upon the quality of school Internet connections. Most school Internet connections currently support many concurrent users. As a result, the bandwidth available per student is often very low. Only 28 percent of all school districts in the country had one Mbps per student, a minimum requirement for effective virtual learning (Tate, 2018). School and classroom access to computers is critical since many students lack such equipment and broadband connections at home.

A New Zealand study on the effects of high-speed broadband on education pointed to savings stemming from lower costs of skill enhancement, as well as reduced cost of course materials and savings on field trips. The result was a $3.6 billion consumer surplus over 20 years. More recently, a study out of Michigan State University's Quello Center revealed that poor Internet connectivity has repercussions that go far beyond the ability to complete homework assignments (Taglang, 2020). In many cases, students will possibly be disadvantaged for life**.** Middle and high school students with high-speed Internet access at home have more digital skills, higher grades, and perform better on standardized tests, such as the SAT**.** Regardless of socioeconomic status, students who cannot access the Internet from home do worse in school and are less likely to attend college or university. The deficit in digital skills also contributes to lower academic success and to these students being less interested in higher-paying STEM careers**.** Students who have only cell phone Internet access, but no complementary devices such as a tablet or notebook computer, are as disadvantaged as students with no access at home**.** Dettling et al. (2015) link the diffusion of zip code-level residential broadband Internet to millions of PSAT and SAT takers' college testing and application outcomes and find that students with access to high-speed Internet in their junior year of high school perform better on the SAT and apply to a higher number and more expansive set of colleges. Effects appear to show that while, on average, high-speed Internet improved students' postsecondary outcomes, it may have increased pre-existing inequities by primarily benefiting those with more resources.

What has COVID-19 taught us?

The World Economic Forum reports that as of March 2020, the OECD estimated that over 421 million children were affected due to school closures announced or implemented in 39 countries. In addition, another 22 countries had announced partial closures. These changes have prompted educational innovations. While most initiatives to date have been limited in scope, and relatively isolated, the pandemic could pave the way for much larger-scale, cross-industry coalitions to be formed around a common educational goal. Moreover, the quality of learning is heavily dependent on the level and quality of digital access. After all, only around 60% of the globe's population is online. K-12 officials are confronting the reality that some students do not have reliable access to the internet at home – particularly those who are from lower-income households (Auxier and Anderson, 2020).

Hamilton County Schools

When COVID-19 made regular school impossible, Ben Coulter, Director of IT for the Hamilton County School District, realized that some 17,000 students (roughly 38 percent) had low or no internet connectivity at home. EPB worked with the schools to provide hotspots in select neighborhoods to enable connectivity.

On July 29, 2020, ***HCS EdConnect*** was announced as a new initiative to provide Internet services to about 28,500 economically challenged students in Hamilton County Schools in the Greater Chattanooga area. Families in the EPB service area with students who participate in HCS EdConnect will receive a router and at least 100 Mbps internet service at no charge. This internet service is at least four times faster than typical educational access offerings from other providers, and it is the only one that delivers symmetrical speeds with no data caps. As a result, HCS EdConnect families will have more than enough broadband capacity and data to participate in video-based learning and other high bandwidth educational applications. The program is structured such that qualified students will maintain their internet services at no charge for at least 10 years if the partnership reaches its full fund-raising goal (Chattanoogan.com).

There are 76 public elementary, middle and high schools in Hamilton County, that serve 44,000 students with 3,500 teachers.[45] The public schools receive broadband service through ENA (Education Networks of America) who in turn subcontract with EPB and Comcast. Each provider serves every school with 750 Mbps connectivity, making for a gig and a half of bandwidth for the school system. Each of 23,000 middle and high school students receives a chrome book as part of *Tech Goes Home*, and teachers are given laptops.

The bandwidth provides redundancy and reliability and enables a wide variety of educational activities from the use of the learning management system (LMS), Canvas, and digital textbooks, to instant video streaming, remote consultations and extra-curricular and after-school activities.[46] High-speed broadband networks have helped expand communication between teacher/school and students and between teacher/school and parents. According to Greg Bagby and Ken Gano, two IT trainers attached to Coulter's office, the bandwidth in classrooms also facilitates interactive capabilities such as Google expeditions. However, no metrics are currently available that link the use of technology to educational outcomes. Schools rely on technology to teach lessons, streamline administrative tasks, conduct teacher/parent communication and support disadvantaged children with special programs. Children can now simultaneously watch live streaming events on large screens in each classroom, Skype with authors across the country, and connect with other children worldwide. Quality images matter in the classroom, where students engage in virtual science experiments, real-time views from the Hubble Space Station illustrate space lessons, and new species are discovered with vivid, life-like images.

In May 2015, The National Science Foundation awarded a $300,000 grant to the Public Education Foundation and University of Southern California (USC) School of Cinematic Arts to support the first-in-the nation cross-country collaboration using the county's gigabit network. With USC, students at Chattanooga's STEM School design experiments to study the effects of human activity on microbial ecosystems both in Chattanooga, as well as a continent away in the Pacific Ocean (Lobo, 2015).

[45] Data from Education Week shows that as of 2018, there were 130,930 public elementary and secondary schools in the U.S. in 13,958 school districts. Roughly 3.2 million full-time equivalent teachers work at, and 51 million students attend public schools. In Tennessee, there are 1,774 public schools catering to just over one million students.

[46] Lobo (2015) reported that the Youth and Family Development (YFD) Centers in the city used high-speed broadband service from EPB to run literacy programs such as Lexia. Without high-speed broadband access, the program would not be possible and to have a similar impact, the YFDs would need at least two additional teachers per site at a cost of roughly $12,480 per teacher per year at $12/hour for 12 hours/week.

All school software can be hosted on the cloud, relieving the need for servers at individual schools. The savings due to cloud-hosting is minimally $5,000 per school per year, or roughly $3.8 million over ten years. Moreover, IT-savvy teachers estimate that the time savings from faster sharing and uploading documents is equivalent to at least one additional part-time employee, i.e. a personnel cost saving of about $29,909 per school year per school (Lobo, 2015). This makes for a ten-year savings in personnel costs of approximately $22.73 million. [47]

The University of Tennessee at Chattanooga

The University of Tennessee at Chattanooga (UTC) has two separate 10 gigabit connections through EPB. This bandwidth provides redundancy and reliability with a utilization rate of 35-40 percent.

The Vice Chancellor of IT at UTC, Vicki Farnsworth, points out that the bandwidth enables UTC to maintain most of their servers on the cloud. These savings amount to roughly $500,000 every five years, or $1 million over a ten-year period. Additionally, she estimates that the bandwidth capacity eliminates the need for at least two staff members in her office, at a cost savings of approximately $200,000 per year, a benefit of $2 million over ten years.

At UTC, high-speed internet access produced productivity gains, according to a former Chief Technology Officer. The campus has not had an outage since the summer of 2009 (Lobo, 2015). Cited benefits related to monitoring safety (i.e. fewer false fire alarms and state-of-the-art classroom alert beacons) and quicker facilities fixes and reduced manpower costs. The 500 security cameras on campus require significant bandwidth. They deliver campus safety and preparedness. Additionally, swipe card access does not require high bandwidth but delivers greater flexibility in fixing problems (e.g. avoided costs of rekeying). The campus is preparing to transition to VoIP and appears to be well-positioned to support the Internet of Things.

A few years ago, UTC, in partnership with The Enterprise Center and US Ignite, acquired and activated a GENI (i.e., Global Environment for Network Innovations) rack. The GENI rack is a 10-gigabit per second broadband pipe that is linked with similar racks in 60 other leading universities in smart cities in the U.S. and internationally. The racks act collectively as a programmable nervous system for researching and deploying the next generation of the Internet and cloud computing. GENI supports next-generation architectures for sharing advanced applications that require symmetric gigabit speeds, advanced local cloud computing (locavore computing) and/or software-defined networking. UTC is the only non-Research tier-1 campus in the country to house a GENI system due to the fiber infrastructure available (Ellis, 2019).

Brian Rogers, Director of Library IT at UTC, notes that the library can now offer streaming services and materials. Moreover, with COVID19-inspired moves to virtual classes, the need for lecture capture and live streaming becomes especially important, and bandwidth becomes critical.

[47] Schools everywhere are facing the fact that 21st-century education is driven by data and the way that it is stored. Data storage on campuses grows by over 50 percent each year. Better duplication practices can save terabytes of storage, improve data access times, and increase overall storage efficiency.

Case Study 14: The Chattanooga Public Library

The Chattanooga Public Library (CPL) has transformed itself from a 20th century institution to one that encourages innovation by offering a public laboratory and educational facility with a focus on information, design, technology, and the applied arts. CPL While traditional library spaces support the consumption of knowledge by offering access to media, the Chattanooga Public Library has combined the traditional approach with one that supports the production, connection, and sharing of knowledge (Lobo, 2015).

In addition to the main facility, the library has four branches in the city. Corinne Hill is the Executive Director of the Chattanooga Public Library. She specializes in incorporating technology into library services. So, when she took over leadership of the Library in 2012, among the first items on her agenda was to bring high-speed fiber connectivity to the Library. Hill contacted the FCC and emphasized the need for anchor institutions in communities that enable people with limited means to access digital resources and information. She recalls when she first took office in 2012, the connection speed was very slow, and systems would frequently lock up. The EPB upgrade along with much needed hardware upgrades transformed the Library, enabling it to develop digital content and digital access. Digital circulation has had a median annual growth rate of 33.4% since 2012, while physical materials circulation has grown by 3.8% in that same time period.

The Library helps reduce the digital divide by offering numerous online resources, in addition to public access computers, free WiFi, circulating chrome books, and WiFi hotspots. **Fig 7.3.1** shows the sharp uptick in digital circulation at the Library since 2012.

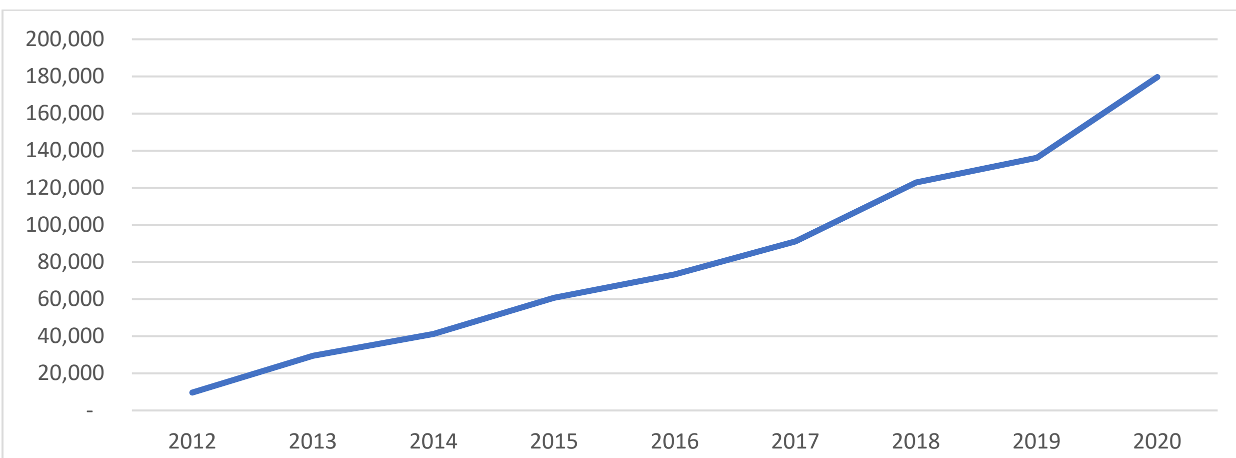

Fig. 7.3.1 Chattanooga Public Library Digital Circulation 2012-2020

When COVID-19 forced the Library to shut its doors, the digital infrastructure made it possible to offer virtual access to the Library's resources within a week. Virtual meeting attendance as well as the digital engagement and reach of the Library has increased sharply since March 2020 as seen in **Fig. 7.3.2**. Note that the April 2020 datapoint has been dropped because a celebrity reader, Leslie Jordan, sharply drove up engagement numbers by 585% that month. In March-May-June 2020, the average monthly social media reach has been about 214,000, up sharply from 55,000 in the previous eight months.

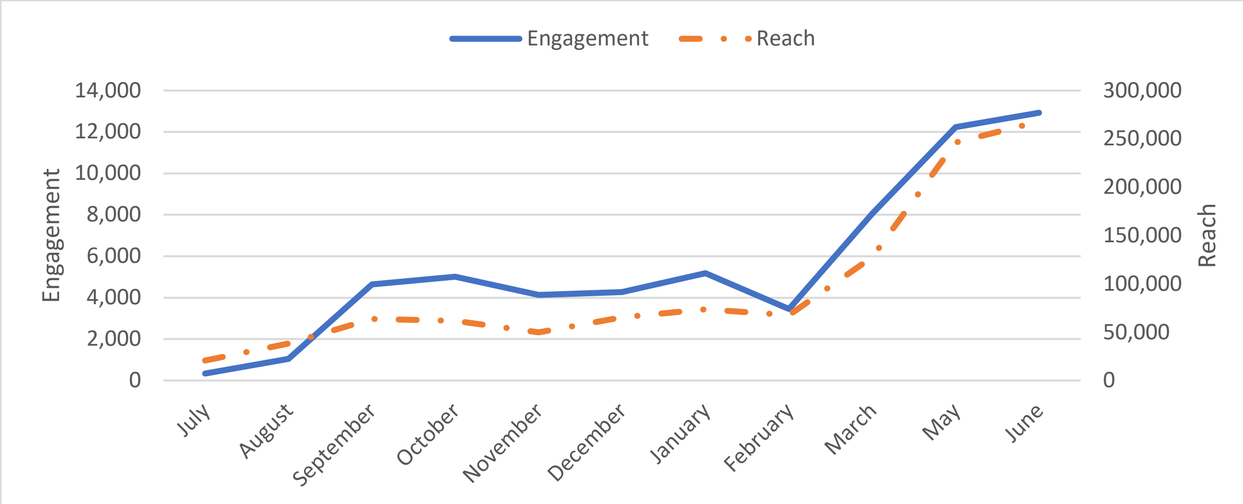

Fig. 7.3.2 CPL Digital Engagement and Reach July 2012–June 2020

Summary

Similar to healthcare, we find local data on education outcomes related to broadband access and adoption inadequate. We piece together benefits of $19.8 million over the past ten years related to server savings and productivity (cost) savings. However, in the case of education, the benefits of high-speed, reliable internet connectivity can mainly be viewed in terms of the costs of not having such a utility. For instance, lack of access results in lower test scores and college and career opportunities and might even disadvantage students for life as the Quello Center reports. Chattanooga mayor, Andy Berke, believes that with the HCS EdConnect Program, the city is the first in the country to "bridge the digital divide" in education by providing free internet to all students in need. He added, "*Through this partnership, we are using our fiber network to improve the lives of thousands of families*." (Brand, 2020).

7.4 Media Publicity

Lobo (2015) notes that since 2010, the fiber optic infrastructure, the "Gig City", and the smart grid have been garnering global awareness and media coverage. A sampling of media sources and articles through 2015 is listed below:

The Guardian – How One City's Super-Fast Internet is Driving a Tech Boom
New York Times – Fast Internet is Chattanooga's New Locomotive
CBS Morning News – Which City has the Fastest Internet in the Nation?
Al Jazeera English – New Technology to Protect US Grid
Thomas Friedman column in the New York Times - Obama's Moment
CNBC – Rebooting Chattanooga's Fortunes
Atlanta Journal Constitution – Technology Thriving
Wired – Where High Speed Internet Meets Smart Grid

Fast Company – A Small City with a Smarter Grid
GreenTech Media – Top 10 Utility Smart Grid Deployments in North America
The Economist – The need for speed
Wall Street Journal – Cities start own efforts to speed up Broadband
Wall Street Journal – Getting “Smart” on Outages
Forbes – The New Metropolis: The New Urban Pioneers

A further sampling of media coverage of the fiber optic infrastructure since 2015 is listed below:

CNN Money – This city is giving super-fast internet to poor students
Forbes – Today's Must-Reads For Business Owners: The Secret To Chattanooga's Tech Surge
CNET – How blazing internet speeds helped Chattanooga shed its smokestack past
businessinsider.com – Chattanooga, Tennessee has found a way to reinvent itself as a startup center of the South
Washington Post – Most Americans want to let cities build and sell homegrown Internet service
CNBC.com – Forget Silicon Valley, these 7 cities are great for start-ups
Gizmodo – The 6 Best Things That Happened to the Internet This Year
AOL.com – US cities that will pay you to live there
The Verge – Tennessee city that fought Comcast and won announces 10Gbps internet
Yahoo! News – New Netflix list ranks the fastest ISPs in the United States
The Daily Beast – Chattanooga Has Its Own Broadband—Why Doesn’t Every City?
INC.com – These 5 Traits Make for The Perfect Startup City
The Hill/Blog – The private model must prevail when it comes to broadband
Wired – Want Real Choice in Broadband? Make These 3 Things Happen
The New Yorker – Why the F.C.C.’s Municipal-Broadband Ruling Matters, Too
Consumer Reports – Are City-Owned Municipal Broadband Networks Better?
Fortune – One of America’s Most Startup-Friendly Cities Is in Tennessee
The PEW Charitable Trust – Despite State Barriers, Cities Push to Expand High-Speed Internet
PBS Newshour – Small towns join forces to bridge the digital divide
PCMag.com – How Chattanooga became a tech hub

This high-quality exposure helps draw the attention of vibrant and innovative workers and entrepreneurial talent to the area. It also draws business investment to the area. We estimate that over the period 2010-2020, the features of the fiber optic infrastructure, i.e. high speed broadband and the smart grid, have brought media attention to Chattanooga and Hamilton County in the form of over 2,200 high-quality print articles, blogs, or radio spots as seen in **Table 7.1**.[48] This media coverage is estimated to have reached over 4 billion viewers/readers resulting in about $47.5 million in the form of advertising-equivalency value.

[48] EPB uses the Meltwater news clipping service along with their own scans of the news to identify the media coverage.

Table 7.1 Gig and Smart Grid Media Coverage

	Total number of stories	Circulation: Unique Visitors	Advertising Equivalency Value
Jan 2010 – Apr 2015*	1,885	3,009,395,237	$24,374,101
Aug 2015 – Apr 2020§	353	1,061,798,749	$23,118,813
Total	2,238	4,071,193,986	$47,492,914

* From Lobo (2015); § Source: EPB.

7.5 Other

7.5.1 Civic Services: Transportation and Public Safety

High speed broadband can enable governments to increase the number and level of public services available to citizens by putting new and existing services online. The potential benefits of e-government result from savings in time and transportation costs involved with visiting local government offices, and savings associated with the reduction in government paperwork. Such benefits can be especially important for the disabled community by promoting greater participation and reducing isolation. Additionally, advanced broadband infrastructure would promote security and public safety. Such services as remote video monitoring of home, children, pets, and remote video monitoring of schools and businesses will enable greater public security. At a broader level, biometric screening at designated entry points/sensitive facilities, and remote surveillance of borders, ports, and airports will promote national security. Importantly, local benefits could include assistance to police, fire, first-responders and emergency personnel in crisis situations.

Case Study 15: The Chattanooga Police Department

The Chattanooga Policy force is led by Chief David Roddy. They use two different camera systems, and a license plate reader, that connect from patrol cars to the intelligence center. "*These cars are like moving offices, and the ability to push through connectivity is critical*," says Chief Roddy.

The fiber infrastructure is critical for the quality of video streamed from 37 cameras located all over the city. These public safety cameras help build trust between the community and the law enforcement officers. Each of the cameras has a dedicated gigabit VLAN connection, and they stream video 24 hours a day to the intelligence center. The data is reviewed for specific crimes (usually, violent crimes) and for specific areas. Chief Roddy and his team examine the data for trends in incidents, shots fired, homicides and other criminal activity. Sometimes a determination is made to move a camera to a different location.

Public safety cameras were first installed in June 2017. Prior to that, the police relied on third party evidence from a crime scene. This was often inconsistent and difficult to bring to court. With the cameras, the evidence is easier to gather and crime files can be closed more rapidly. The 24-hour video feed is stored for up to 30 days on a local server, unless the evidence is required in a court of law. During the first six months, there were a total of 30 requests for video from officers and investigators for different cases, including five homicides and 13 shootings. Of the 30 requests, 22 resulted in usable video evidence in court.

The video feed also helps break the "shooting cycle", i.e. a shooter/weapon involved in one or more incidents has a very high likelihood of shooting again.

A key metric of the effectiveness of a police force is its ability to clear homicide cases. In 2016, prior to installation of the cameras, CPD had a 40% clearance rate. Since then, the clearance rate has jumped from 60% in 2018 to the mid-80% in 2018 and to 70% (above the national average of 60%) in the past couple of years. Chief Roddy attributes this improvement in performance to the information streamed from the 37 cameras in the city. In turn, this improved performance builds trust in the community.

Sgt Billy Atwell runs the real time intelligence center of the CPD. He believes that the high-speed fiber broadband saves him considerable time when it comes to downloading and uploading files to the evidence database in the cloud.

The social distancing challenge of COVID-19 means that officers cannot have true engagements and close relationships with the community, whether it be "coffee with a cop", or summer camps, youth engagements, or even cops in schools. Chief Roddy is hopeful this pandemic will end and permit his department to re-engage meaningfully with the community.

A quantifiable benefit to Hamilton County stems from the use of the Intelligent Transportation System (ITS). The project received funding from the Department of Transportation to achieve two goals: 1) to identify optimal strategies to minimize congestion and 2) to minimize delay during incidents leading to reductions in secondary accidents within the transportation network. The project requires significant bandwidth and has a six-year build out period. Currently, data is being collected that will help quantify this benefit in the months ahead.

Kevin Comstock is the Smart Cities Director for the City of Chattanooga. He oversees the ITS. Comstock says the regional ITS will be able to bring together the mapping communications connection on a single web accessible map or smart phone application and provide information in real time on the status of the transportation network. The regional ITS will also be able to get out messages in a timely fashion so that users of the transportation network will have the opportunity to make an informed choice on the route or perhaps even the mode they should utilize. Subsequent phases of the ITS project will deploy a CCTV network throughout the region to monitor and detect incidents. This information, in turn, can be shared with first responders and other agencies.

Comstock's department is working with UTC's Center for Urban Informatics and Progress (CUIP) to study urban mobility. CUIP recently was named an IDC winner for the project "911 Project – Predicting Hotspots for Accidents." In naming the winners of the 2020 North America Smart Cities Awards, IDC described the winning entry from Chattanooga in the "Police and Law Enforcement and Emergency Management" category as follows:

A logistics hub located at the very heart of the United States' southeastern "freight alley," Chattanooga, TN, has been called "The Silicon Valley of Trucking." However, a combination of traffic volume, geographic centrality and unique geology have led to an increase in traffic accidents and fatalities every year since 2015, with roadway accidents now the leading cause of death for residents under the age of 55. The Chattanooga Smart Community Collaborative

(CCSC), the University of Tennessee at Chattanooga's Center for Urban Informatics and Progress (CUIP) launched the "911 Project – Predicting Hotspots for Accidents" in early 2018. CUIP leveraged machine learning, specifically multilayer perceptron (MLP) neural network models, to analyze both historic and current 911 data to identify accident trends. This dataset is cross-referenced with DarkSky weather data, roadway geometric data through TDOT's ETRIMS database, and accident time, date, latitude and longitude. The dataset is then used to create a visualization of accident "hotspots" within a virtual grid of Chattanooga helping to determine mitigation strategies.

Preliminary work suggests that the CUIP model is 87 percent accurate as a predictor of traffic accidents. Comstock's work includes overseeing cameras on 75 intersections, designed to track pollutants, types of vehicles, traffic congestion. Bandwidth is key because of amount of data being streamed daily. Comstock believes this project will enable the City to reduce traffic delay, air pollution and fuel use by 18 to 20 percent, and reduce fatal crashes.[49] Over a 15-year service period of the project the City is expected to receive considerable benefits in fuel savings of approximately 86 million gallons. Additional work with ORNL on a digital twin will further enhance the benefits of the project.

"*The fiber network is our greatest advantage*," says Comstock.

Case Study 16: The Center for Urban Informatics and Progress

The Center for Urban Informatics and Progress (CUIP), housed at the University of Tennessee at Chattanooga, came into existence in 2018 to engage experts across the UT system in cross disciplinary research focused on solutions to modern urban challenges such as energy, mobility, healthcare, public safety, water and waste that directly benefit Chattanooga, while developing methods and models for use around the world. CUIP works with EPB, TVA, Siskin Hospital, Co.Lab, the Enterprise Center, Hamilton County, the City of Chattanooga and the Chattanooga Department of Transportation. It also collaborates on research projects with the U.S. Department of Energy, the National Science Foundation, Oak Ridge National Laboratory, Lyndhurst Foundation, the State of Tennessee, and with industry.

The CUIP website points out that "*The story of the CUIP…is inextricably tied to that of Chattanooga's internet: without the Gig, the CUIP could not do what it is doing. There is far too much data moving to be plausibly housed anywhere nearby*." Millions of data points stream into the CUIP every day – audio, video, air-quality, LIDAR – all of which is used to learn how our city moves and works together, identifying problem spots, and crafting solutions.

Under the direction of Dr. Mina Sartipi, Guerry Professor of Computer Science and Director of CUIP, one CUIP project uses artificial intelligence, historical 911 emergency data, roadway geometrics and weather data to create a computer model that accurately predicts where and when roadway accidents will take place. The project won the IDC award in the "Police and Law

[49] As indicated on the fueleconomy.gov website "*Idling gets 0 miles per gallon and costs as much as $0.04 per minute, (per vehicle)*."

Enforcement and Emergency Management" category.

CUIP uses the MLK Smart Corridor as a smart city and connected vehicle testbed. Currently the testbed is being used for pedestrian safety, connected vehicle / infrastructure, and wireless connectivity projects. Researchers at CUIP see the testbed as a sandbox in which they can try a lot of different projects that can be expanded to other parts of the city and the region. This means fewer traffic accidents, fewer health issues like strokes, and smarter use of energy resources. The testbed recently received a $1.9 million grant from the U.S. Department of Energy.

A second grant of $1.75 million was awarded to the Chattanooga Area Regional Transportation Authority, Vanderbilt University, and CUIP to help make the public transit system more efficient.

CUIP is currently addressing a host of research questions, including: How does public WiFi affect the quality of life in our neighborhoods? How can wireless sensor technology be used to monitor stroke patients? How can deep learning be used to optimize energy usage? How can vehicle-to-vehicle and vehicle-to-infrastructure communication be used to improve mobility, health and pollution outcomes in the city?

7.5.2 The City of Chattanooga

Brent Messer has been the Chief Information Officer for the City of Chattanooga since 2014. A software engineer by training, Messer oversees technology use for over 22 departments and over 100 buildings, including city hall, and roughly 2500 employees that work for the City. He manages a gigabit VLAN service through EPB. Apart from two server racks, the City's servers are cloud-based and cyber-secure. He also uses a colocation service from EPB for disaster recovery purposes. He believes the service provides plenty of redundancy and positions the City well for times when bandwidth needs to be ramped up.

Messer believes the biggest benefit of the fiber infrastructure in the City has been the economic development that it has attracted. It has, however, spotlighted the digital divide that characterizes much of America.

Of the 22 departments under City Hall, the Police Department and Public Works are among the largest users of bandwidth. The police use a combination of cellular and real time intelligence, and real time streaming cameras that generate data to be used for predictive analytics, as previously mentioned. The Department of Transportation also deploys cameras at 75 intersections as part of the Intelligent Transportation System to detect traffic patterns and prevent accidents and unnecessary pollution. Plans are afoot to add cameras to every garbage truck in the city to gather data on a variety of issues including road quality. The City plans to use machine learning techniques to facilitate predictive analytics.

In March 2020, the City of Chattanooga launched an open data portal via its Office of Performance Management and Open Data (OPMOD). Visitors to *chattadata.org* can access public datasets, visualizations, and performance dashboards. OPMOD is charged with creating citizen-focused, data-driven information for policy and public consumption. Their work started about five years ago.

To date, OPMOD has made available to the public a slew of city data ranging from assessments of employees eligible for retirement, to the traffic at a given intersection, to purchasing and contract information and an "open checkbook" that serves as a register of expenditures by the city, and enables everyone to see every check the city writes, just like a checkbook (Taylor, 2020). The data portal currently contains 136 datasets and 59 filtered views. Many more datasets are expected to be added in the future according to Tim Moreland, Director of OPMOD, and Andrew Sevigny, OPMOD's Performance Analyst. Using data from the most recent American Community Survey, census tracts are identified that have high unemployment rates, and therefore are good targets for economic outreach. Likewise, measures of traffic flow are used as a first step to understanding connected transportation in the city. The portal also taps into several national datasets to report local economic conditions.

In 2015, Chattanooga began to offer free Wi-Fi access via NoogaNet, a network available at city-owned spaces and buildings. The network is among the best nationally and is included in the ranks of initiatives in cities such as San Francisco and New York (Pare, 2015).

7.5.3 Chattanooga Metropolitan Airport Authority

Terry Hart is the CEO of the CMAA, and the 2019 winner of the Chattanooga "Manager of the Year". Thirteen years ago he took over a sleepy airport in Chattanooga. Since then, the growth in airport traffic has been significant. In 2008, about 250,000 people flew in and out of Chattanooga. By 2019, that number had jumped to 550,000. Why? Hart explains, "*Look what's happening in the economy in this region; people travel here for leisure and business*." [50]

In drumming up new business, Hart says he always brings up what EPB did with the development and rollout of the fiber network. It has attracted a lot of people and firms. Developments in the community have changed the perception of the city and the region. Today, the big three airlines (Delta, United and American) fly out of Chattanooga and the City has direct flights to Atlanta, Charlotte, Chicago, Dallas, Detroit, New York City, Orlando, Tampa and Washington DC.

In 2010, the CMAA got into the solar business. Airports had a bad rap about polluting/poor air quality. This three-phase project was designed to produce electricity through a solar farm, which in turn was sold to TVA. Today, the revenue from TVA offsets the electricity fees from EPB. Recently, EPB placed a battery storage facility at the airport to help mitigate power outages. CMAA is also working with EPB to place a natural gas generator to help supplement power at peak demand times. The smart grid benefits the airport and surrounding areas.

[50] COVID-19 has taken a big bite out of commercial, corporate, and cargo transport. In April 2020, enplanements were down 95 percent. The CMAA has gone ahead with a planned construction of a new parking garage. Hart believes the airport is in good financial shape, with no debt. While sustained telecommuting may hurt the airport down the road, he believes over time, people will prefer the face-to-face interaction.

CHAPTER 8. CONCLUSION

In a five-year lookback at the realized value of fiber optic infrastructure in Hamilton County, Lobo (2015) estimated that the infrastructure had "*generated incremental economic and social benefits ranging from $865.3 million to $1.3 billion while additionally creating between 2,800 and 5,200 new jobs*" over the period 2011-2015. This study sought to extend that analysis in analyzing the realized economic value of fiber optic infrastructure in Hamilton County and the city of Chattanooga, over a (roughly) 10-year period from 2011 to March 2020.

We find that the economic value of the fiber high-speed broadband and the smart grid, minimally exceeds $2.69 billion and 9,516 jobs over the period 2011-2020. The jobs represent 40 percent of all jobs created in Hamilton County in that period. The value exceeds the costs of the project by over $2.20 billion, or by a factor of 4.42.[51] Approximately 52 percent of the value is manifested in economic development, i.e. new business investments, real estate development, startup funding and payments-in-lieu of taxes (PILOT). The smart grid has generated 28 percent of the estimated value in less than an eight-year period from 2012. The remainder of calculated value stems from business efficiencies, and household and community effects as seen in **Fig. 8.1**. Each county resident is estimated to have benefited by about $646 per year (or $5,978 over slightly more than nine years) from the incremental value generated by the fiber optic infrastructure.

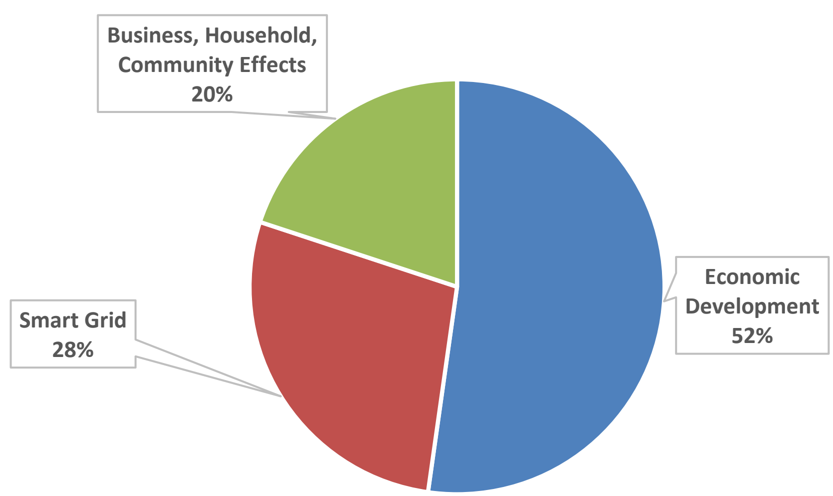

Fig. 8.1 The Economic Value of Fiber Optic Infrastructure in Hamilton County TN

The estimates in this study suggest that early projections of the effects of fiber optic infrastructure in Hamilton County were conservative. In the initial study of the likely effects of the fiber infrastructure, Lobo, Ghosh and Novobilski (2006) estimated that the fiber-to-the-home/business build-out would take ten years and generate benefits net of costs of $438 million in addition to about 2,600 new jobs. The study failed to consider the effects of a possible smart grid, or that the build-out would be completed in half the projected time. In assessing the realized value of the infrastructure, Lobo (2015), as previously mentioned, estimated economic and social benefits of

[51] The total costs were compounded at the average ten-year Treasury yield over the period 2011-2019.

the fiber infrastructure ranging from $865.3 million to $1.3 billion and between 2,800 and 5,200 new jobs over the period 2011-2015. The findings in this study with respect to employment effects are consistent with the findings from the five-year lookback. However, the estimate of overall value continues to exceed expectations.

Furthermore, this study likely underestimates the value of the fiber infrastructure because it has not been able to adequately quantify the local effects of telehealth, education and civic services. The case studies reveal that the infrastructure creates value in ways that are hard to measure. For instance, interviews with law enforcement officials indicate that there is value in the quicker resolution of criminal cases due to the streaming video feed from the public safety cameras. Similarly, hospital officials point to better health outcomes due to quicker communication capabilities. Current approaches to valuing lives saved could significantly boost the healthcare estimates discussed in this study. Similarly, a reliable, low-latency, high-speed fiber broadband connection has enabled the public schools to maintain continuity in learning in COVID times, but we have not quantified the possible value associated with learning outcomes. Community-focused studies such as this one help to shape the questions that social scientists must answer.

A Brookings Metro's COVID-19 Analysis points out that the pandemic "*…isn't making broadband essential, it is exposing that it always was.*" The pandemic is accelerating nascent trends, while also altering the way we live, work and interact with others, both as individuals and as communities. With some 90 percent of Morgan Stanley's 80,000 employees have been working from home, James Gorman, Chairman of Morgan Stanley, believes that the bank "can operate with no footprint," (Cuozzo, 2020). As the average household daily usage of broadband has jumped in the wake of the pandemic, the use of upstream broadband - used for video conferencing and calling - increased at a faster clip overall than the more traditional internet activities such as streaming and gaming, which are known as downstream internet usage. Mark Trudeau, chief executive of the broadband data firm OpenVault, points out that while overall broadband usage eased in the second quarter, he believes the second half of 2020 might look different, citing the increase in upstream usage, a consumer shift to higher speeds and other question marks such as distance learning, continued work from home and the growing number of COVID-19 cases in some U.S. states. "*These are all flashing signals that higher consumption levels lie ahead,*" Mr. Trudeau said (Rizzo and Click, 2020).

The pandemic will make it essential for city planners and business executives to develop and systematically gather data on how they deliver services virtually and how households and businesses consumer bandwidth. Consequently, future studies of this nature will have cleaner and more readily available data to work with. Local efforts such as Chattadata.org are already moving in that direction. Other sources of real-time data such as GoDaddy venture activity, Adobe Analytics, Google Analytics and such will be indispensable as scientists and policy planners begin to tease out causal relationships and target policy actions.

When the original National Broadband Plan was being drafted in 2010, there was no political consensus that universal broadband was an important policy priority (Levin, 2020). Today there is. The COVID-19 crisis is boosting momentum for major broadband legislation, highlighting the widespread lack of high-speed internet in U.S. homes. Chattanooga and Hamilton County are indeed fortunate to have quality high-speed, symmetric fiber broadband. Lawmakers, locally and nationally, must act quickly to close the digital divide to promote an inclusive and globally competitive economy where the digital have-nots are not excluded. The HCS EdConnect initiative to connect every low-income household in Hamilton County to 100 Mbps broadband is an example others may want to emulate.

Every second of the day, 88,555 Gigabytes of internet traffic is generated (see **Fig. 8.2**). By 2025, over 463 exabytes of data will be created each day globally (Desjardins, 2019). When artificial intelligence (AI) works with the internet of things (IoT), we get AIoT, a smart connected network of devices that seamlessly communicate over the internet, creating unimaginable volumes of data. AIoT will drive wearables, smart homes, smart cities and smart industries (Newman, 2020).

Fig. 8.2 This is what happens in an internet minute (2019)

Source: The Visual Capitalist

Fiber optic infrastructure is essential infrastructure because reliable, low-latency, high-speed broadband and a smart grid are essential. This study has shown, again, that the true economic value of the fiber infrastructure is much greater than the cost of installing and maintaining the infrastructure. The estimates for 2011-2020 exceed the projections made at the time the infrastructure was planned, and also exceed a linear extrapolation of estimates based on the period 2011-2015. It is very likely that as more granular local usage data becomes available, new and improved measures of value will add to the estimates reported in this study.

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