Research & Policy INsights

BENEFIT-COST ANALYSIS FOR IMPLEMENTATION OF RURAL BROADBAND IN THE TIPMONT COOPERATIVE IN INDIANA

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Alison Grant is currently pursuing her Ph.D. degree in the department of Agricultural Economics at Purdue University. She possesses a Master of Science degree in Food, Agricultural and Resource Economics from the University of Guelph in Ontario, Canada. Trained as an agricultural and resource economist, Alison Grant's research has focused on the economic impact of perceived environmental externalities using econometric analysis. Specific research themes include modeling the impact of aggregate sites on surrounding rural residential property values; examination of the factors that affect farmland values and rental rates; determining the economic costs of pesticide policy in Ontario; and exploration into the application of water markets.

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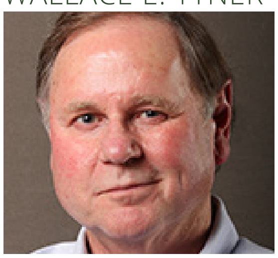

Professor Tyner's recent research interests are in the area of climate, energy, agricultural and natural resource policy analysis. His work in energy economics has encompassed oil, natural gas, coal, oil shale, biomass, biofuels from agricultural sources, and solar and wind energy. Much of his recent work has focused on economic and policy analysis for biofuels and the interplay between biofuels policies and other energy policies. He has over 330 professional papers including three books and 115+ journal papers, published abstracts and book chapters. His work has been cited over 5,700 times according to Google Scholar with an h index of 34 and i10 index of 97. His current research focuses on renewable energy policy issues and the links among energy, agriculture and climate change. He was Co-chair of the National Academy of Science Committee on the Economic and Environmental Impacts of Biofuels (2011). In 2016, he chaired a National Academy panel on advanced biofuels. He teaches a graduate course in benefit-cost analysis, which incorporates risk into the economic and financial analysis of investment projects.

Executive Summary

The objective of this study is to estimate the costs and benefits of rural broadband for the Tipmont Rural Electric Cooperative service territory. It does so by analyzing the "real world" costs of providing broadband service to households in a targeted multi-county area of Indiana, and estimating the benefits that can accrue to these households and the surrounding economy. This analysis can offer a valuable framework for assessing the net benefit of providing broadband services across rural areas of Indiana.

There are three major components of the study that combine to achieve the overall estimates of benefits and costs of rural broadband for the Tipmont service territory. The first component delves into the cost of implementing the broadband service for the entire Tipmont territory. The cost estimates include all the capital and operating costs for the system, which was information provided to the research team by the Tipmont Rural Electric Member Cooperative (REMC) team. The second component examines the price that Tipmont will charge and the anticipated participation rate given that price. The third component estimates the benefits that could be realized from the provision of rural broadband in the Tipmont service area. These added benefits represent the value to society in terms of the provision of broadband service. Some benefits cannot be captured in private markets because they are in the form of externalities or are public goods, for which there is no market price. However, they do represent genuine economic gains. The main report also provides basic background on the current situation in the Tipmont service area.

Table E1 provides the net present value (NPV) for benefits and costs in each category over a 20 year time period. We also calculate a net benefit per member of the cooperative, as well as the net benefit to each member per year. In addition, another common metric used in benefit-cost analysis is the benefit-cost ratio, which is the ratio of the NPV of all benefits divided by the NPV of costs.

The net present value column is the discounted value of all the benefit and cost categories over a range of categories. Some of the most important areas for benefits provided in the literature are telemedicine, education, business investment and general economic development, farm income changes, civic engagement, and property values. While benefits are not limited to these areas, these represent areas that have received the most attention in past studies. We build on the existing literature and/or established benefit-cost analysis methods to estimate benefits in each of these areas. The specific methodologies for calculating each of these benefits are described more fully in the report.

For telemedicine, the following categories were used to quantify the total benefit: reducing the physician time required for treatment and diagnosis, transportation savings for patients, missed work income savings, initial health consultation via web and reduced use of emergency room and other expensive hospital facilities. Education benefits were estimated using the total value of broadband to students, as well as massive open online courses (MOCs) for continuing education.[1] The value that broadband has contributed to economic growth in rural areas was estimated through total business investment and job creation. Increased farm profitability was estimated through the valuation of ease of communication with suppliers and market outlets, access to extension and other farm practice information, quicker access to weather information that could impact management decisions, and generally improved farm management practices.

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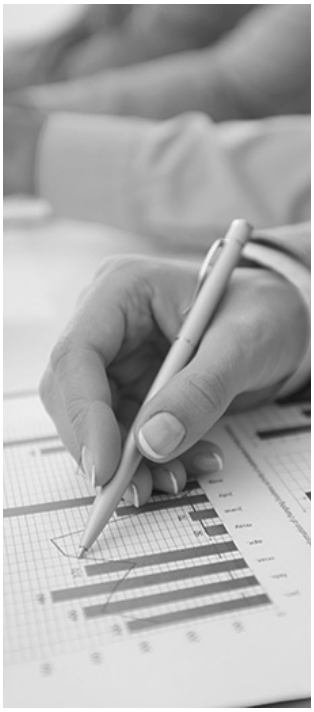
1 These courses are also called Massive Online Open Courses (MOOCs) in the literature.

Table E1. Benefit-cost summary for the different benefit categories (current $USD)

Item	Net present values
Capital cost	99,804,558
Operating cost	89,613,882
Total cost	189,418,440
Telemedicine	
Primary care savings	22,977,791
Specialist	28,633,511
Transport	671,568
Missed work	7,961,549
Pharmacy	20,992,056
Imaging	4,255,146
Web consultation	5,106,176
Urgent care	21,701,247
Emergency care	110,986,276
Total telemedicine	223,285,320
K-12 education	18,981,795
Adult education	103,672,388
Multiplier impacts	187,524,256
Consumer savings	106,946,014
Farm income increase	7,165,348
System revenue	102,123,515
Total benefit	**749,698,635**
Net benefits	**560,280,195**

In conclusion, the net present value (NPV) of benefits of rural broadband in this service area far exceed the costs over a 20-year time horizon. In fact, the net benefit per member is $24,757 and $2,158 per member per year. The benefit-cost ratio is 3.96 meaning that approximately $4 is returned for every $1 spent by Tipmont. Another important metric is NPV of revenue divided by NPV of total cost, which is 0.54. This means that public sector support for this investment not only is warranted, but required. While large benefits are estimated, many accrue to the general public and not the broadband provider. This study provides evidence to suggest that investment in rural broadband is vital for rural areas in Indiana and America, and should be seriously considered by state and federal governments.



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We are pleased to acknowledge Tipmont Rural Electric Member Cooperative for financial support for this research.

Introduction

The current media has a host of stories about the digital economy, focusing on the importance of digital access for economic development and growth, and overall economic well-being. Developing countries in particular are seeing gains in expanding access to digital technology. Thomas Friedman writes about its importance in India:

> *Every Indian, rich or poor, goes into a field office, has fingerprints and irises scanned into a biometric database and then linked to the individual's 12-digit ID number with basic identifiers: name, address, date of birth and sex. When the Congress Party left office in 2014, and Narendra Modi's Bharatiya Janata Party took over, Modi continued and impressively energized the Aadhaar project, bringing it today to 1.18 billion users, out of a population of about 1.3 billion.*
>
> *In a country where many poor people lacked any form of ID, like a birth certificate or a driver's license, this has been a revolution, because they can now open a bank account and get government aid sent directly to them — rather than having bureaucrats, bankers or postal workers skim off 30 percent each year through the mail — and then link their bank account to their mobile phones, from which they can buy, sell, transfer money and receive payments digitally anytime anywhere.*
>
> *When the British laid railroads in India it led to the more efficient extraction of natural resources. Now the Indian government, through the combination of a trusted unique ID platform — tied to cellphones and mobile bank accounts — is creating a kind of digital railroad enabling the more efficient empowerment of human resources.*
>
> *"It's transforming the lives of ordinary people," explained Alok Kshirsagar, a McKinsey partner based in Mumbai. "Millions are already benefiting from digital payments and credit. There are already more than 30 percent productivity gains when digital capabilities are used in agriculture, transportation and manufacturing. We are in the early stages of a transformation that could generate as much as $1 trillion in economic value over the next seven to 10 years [1]."*
>
> **- Thomas Friedman**

The Economist magazine calls data the fuel of the future:

> Data are to this century what oil was to the last one: a driver of growth and change. Flows of data have created new infrastructure, new businesses, new monopolies, new politics and—crucially—new economics. Digital information is unlike any previous resource; it is extracted, refined, valued, bought and sold in different ways. It changes the rules for markets and it demands new approaches from regulators [2].
>
> **- The Economist Magazine**

The Economist also views digital technology as playing a key role in future economic development in Africa:

> Yet, there is also reason to hope that even if technology is not a panacea, it can still help reduce some of the costs and frictions of doing business in Africa. A recent paper for the World Bank found that African firms using the internet are nearly four times as productive per employee as those that do not. But until just a few years ago most firms on the continent did not get to enjoy the benefits of higher productivity for lack of internet connections [3].
>
> **- The Economist Magazine**

These commentaries make clear that digital technology is crucial in the developing world and may position developing countries to rapidly accelerate their rate of economic growth and development. Digital technology and broadband internet access are as important as railroads or energy have been in the past.

The same is true in rich countries, where the digital divide can be quite large between those with and without digital access. Greenstein and McDevitt conducted a study on the impact of internet access in 30 OECD (richer) countries and concluded:

> The scale of the broadband bonus in other countries is comparable to the size of the broadband economies in those countries. Countries with large Internet economies, such as the United States, Japan, and Germany, are receiving large economic bonuses from investment in broadband. Countries with smaller Internet economies receive smaller levels of bonuses, but bonuses in proportion to their scale of Internet use [4].
>
> **- Greenstein and McDevitt**

In other words, investment in broadband has paid off for the rich countries. Boston Consulting Group considers broadband and the many facets it enables (like artificial intelligence) to be Industry 4.0 – the fourth wave of technical advancement [5]. Gallardo and Rembert estimate that there are 12.1 million U.S. households without access to even basic (25 Mbps download and 3 Mbps upload) internet access in the U.S., and 6.2 million of those households are located in rural areas [6]. With 60 percent market penetration for that basic internet access in rural areas, they estimate that the net benefits over 15 years would be $68.1 billion. There are many other studies touting the very large anticipated benefits of rural broadband access. Deveraj, et al. discuss the huge changes associated with the "digital society," and make it clear that without good connectivity, rural areas can fall into the losing end of the digital divide [7]. Kuttner describes the impact of rural broadband as follows:

> In the long run, the economic impact of rural broadband will be more important for the role it plays in changing what the economy is. Information technology shows an amazing capability to create new services. It has also disrupted the role that location plays in the economy. Broadband networks have nearly erased the cost of moving information. Broadband networks allow that disruptive role to happen. This disruption will reach as far as the broadband speed required to support these uses will allow [8].
>
> **- Kuttner**

Yet, even with mounting evidence that benefits far exceed costs, there has been little provision and adoption of rural broadband. Why is this the case? There may be multiple factors. Certainly, one is cost. It is far more expensive to provide high speed internet service in rural areas because of the low population density. Another reason may be that rural electric cooperatives that provide electricity to rural areas may not see it as their mandate to offer broadband. Yet, just as provision of electricity to rural areas had profound effects on economic development and well-being in rural areas, provision of high-speed broadband today could spur the same kind of improvement in economic well-being for rural areas. Before the advent of rural electric cooperatives and the push for rural electrification, we could not even begin to imagine all the benefits that rural electrification would bring. It is very difficult to put dollar values on changes we foresee happening, but don't know yet exactly how they will play out. Another important reason why rural co-ops have not, thus far, generally moved into this business area could be poor understanding of the costs and benefits associated with rural broadband. In fact, that is the objective of this study – to estimate the costs and benefits for a specific case the Tipmont Rural Electric Cooperative. The idea is that with estimation of specific benefits and costs in a real world concrete case, we would better understand the value of provision of rural broadband. The results of this very detailed and concrete study could become the basis for extrapolating to the state of Indiana with appropriate extrapolation factors.

Overall Approach

An important first step in this project, as is the case in most research projects, was to undertake a review of the existing literature on rural broadband and on techniques for estimating benefits for the different application areas. The literature review has been published as a separate report [9]. We draw heavily on that literature to derive the benefit estimates.

The Tipmont Service Area

Most of the Tipmont customers reside in four Indiana counties – Clinton, Fountain, Montgomery and Tippecanoe, with about three-quarters being in Tippecanoe County. Less than one percent of total customers reside in neighboring counties. Figure 1 is a map of the Tipmont service territory. Table 1 provides income data Tipmont obtained from an external source. The customer household income as represented by data from this survey is considerably higher than the census household income for the counties, which is approximately $44,000.

Table 1. Demographic data on household income for the Tipmont service area

Income Categories	Count of Households	Sum of salaries using midpoints of categories ($15,000 for 1st category, $125,000 for last category)
Less than $15,000	361	$5,415,000
$15,000 - $19,999	416	$7,280,000
$20,000 - $29,999	742	$18,550,000
$30,000 - $39,999	1,335	$46,725,000
$40,000 - $49,999	1,843	$82,935,000
$50,000 - $74,999	5,003	$312,687,500
$75,000 - $99,999	3,054	$267,225,000
$100,000 - $124,999	1,859	$209,137,500
Greater than $124,999	2,276	$284,500,000
Total Number of Households	**16,889**	**$73,092 (Sum of all salaries/total number of households)**

Table 2 provides the level of education obtained from an external source on 12,919 Tipmont customers. For this fraction of their customers, over half graduated from college or obtained a graduate degree and about 46 percent completed high school. However, information was available for only about 57 percent of the Tipmont customers, so one cannot be sure about the representativeness of the data.

Another important question is what internet or broadband service is currently available to Tipmont customers. As part of a larger survey, Tipmont customers were asked about their current internet or broadband access, but the results from those questions are inconclusive. It appears that many customers have some form of internet access, but often quite slow and sometimes only via cell phone. So far as we could determine from the survey, very few customers have the high-speed broadband access that would be needed to obtain most of the benefits estimated in this study.

Table 2. Educational attainment data

Category	Numbers	Percent
Completed high school	5,931	45.9%
Attended vocational technical	84	0.7%
Completed college	4,637	35.9%
Completed graduate	2,267	17.5%
Grand Total	**12,919**	**100%**

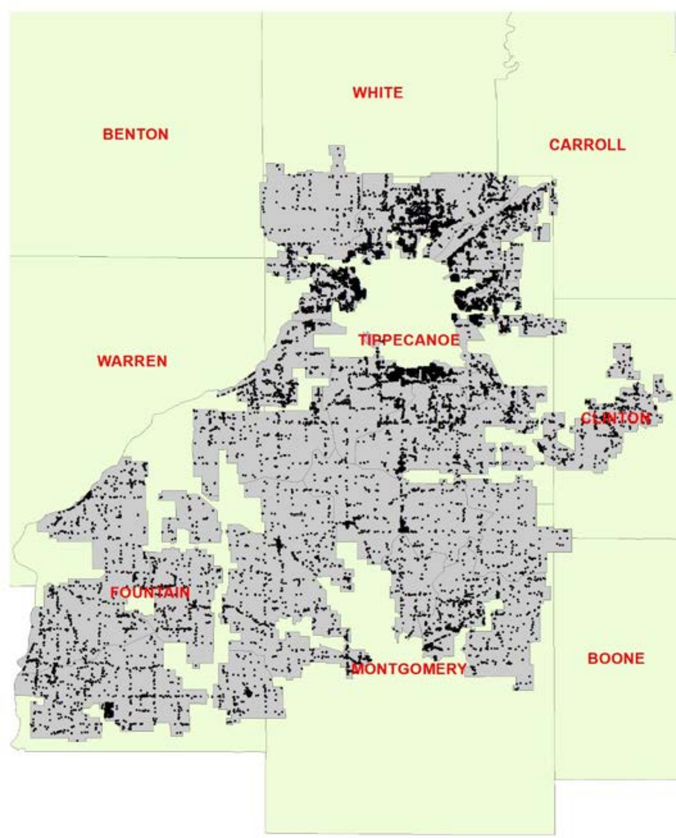
Key Assumptions

Each benefit category delineated below will specify the specific assumption used for estimating benefits in that category. However, there are some common assumptions that are used for all the benefit and cost calculations, and these are provided in Table 3. The base monthly fee is assumed to be $60 for the broadband service. If the customer takes television or phone, those are assumed to be passed on at cost. Given that monthly fee, the assumed take rate is 58 percent, which comes from the research performed by Professor Widmar, which is explained below. The take rate reaches 58 percent in year three, and the rates for years one and two are included in Table 3. We also assume that the customer base grows by an amount of 0.75 percent each year until year 10 and remains constant afterwards. This means that the customer base in year three of 22,631 grows to 23,846 in year 10 and remains at that level through year 20. We recognize this may be a conservative assumption, but felt it prudent not to project growth beyond year 10. The discount rate (interest rate) used for all the calculations is six percent in real terms.

Table 3.
Common assumptions used in the analysis

Assumption	Value
Base take rate	0.58
Take rate growth 4+	0.0075
Take rate year 1	0.145
Take rate year 2	0.377
Take rate year 3	0.58
Total households: years 1-3	22,631
Total households: years 10+	23,846
Monthly fee	$60
Discount rate	6%

Figure 1 Tipmont service territory



Source: Tipmont REMC (2018)

Major components of the analysis

There are three major components of the study that combine to achieve the overall estimates of benefits and costs of rural broadband for the Tipmont service territory. The first component covers the cost of implementing the broadband service for the entire Tipmont territory. The cost estimates were provided to the study team by Tipmont and include all the capital and operating costs for the system. Tipmont currently envisions a base speed of 100 Mbps or higher both for upload and download. The cost is detailed in section V below.

The second component is determination of the price that Tipmont will charge and the anticipated participation rate given that price. At this point, Tipmont anticipates charging approximately $60/month for the basic internet service described above. Professor Nicole Widmar of Purdue University conducted survey work on willingness to pay for internet service under various conditions. The equations she developed are used to determine the base participation rate of 58 percent.

The third component is estimation of the benefits that could be realized from the provision of rural broadband in the Tipmont service area. The benefits are expected to be considerably higher than what the customers will actually pay for the service. These added benefits represent the value to society of provision of the broadband service. Many of the benefits cannot be captured in private markets because they are in the form of what economists call externalities or are public goods, for which there is no market price. The fact that many of the benefits are public goods or effects external to markets makes benefit estimation much more difficult, but fortunately techniques have been developed to estimate benefits under these conditions, and it is these techniques that are applied in this study.

Benefit categories

It is clear from the literature that rural broadband is expected to provide benefits in a variety of areas. Some of the most important are telemedicine, education, business investment and general economic development, farm income, civic engagement and property values. While benefits are not limited to these areas, these are the areas that have received the most attention in prior studies and the areas with greatest potential for benefits. What this means, of course, is that the estimates we produce are a conservative assessment of total benefits because we are not able to capture all possible benefits. In the rest of this section, we will provide a brief summary of the approach we are using in each of these areas. Section III provides the actual benefit estimations for each category.

Telemedicine

For telemedicine, we follow the categorical benefit approach used by Whitacre [10]. When telemedicine is used effectively, benefits can accrue through reducing the physician’s time required for treatment and diagnosis, transportation savings for patients, missed work income savings, initial health consultation via web, health improvement, improved health knowledge and improved self-care, and reduced use of emergency room and other expensive hospital facilities.

Education

There are numerous possibilities for benefits in education. Massive online courses (MOCs) are only possible with broadband access. They are becoming increasingly important in continuing education as well as a means of students participating in their regular classes via the web instead of the traditional classroom [11]. The expectation is that MOCs will continue to grow and that rural access will be essential for rural citizens to have a level playing field with their urban counterparts. Computer classes are generally less expensive and more cost effective than traditional classroom based learning, so with rural broadband, citizens will have access to lower cost but effective education and job skill upgrade options.

In addition, distance education is increasingly a part of elementary and secondary education as well as college and continuing adult education. Today, students can complete and turn in their homework exercises via the web. They can also communicate with their teachers electronically. Not only today, but even more so in the future, access to broadband will significantly improve student performance.

Business investment and general economic development

Numerous studies have concluded that broadband access is an important factor contributing to business investment and job creation as well as general economic growth in rural areas. Whitacre et al. concluded that broadband adoption has a positive impact on economic growth and negatively impacted unemployment in rural areas [12]. They also concluded that rural broadband adoption leads to improved median household incomes and an increased share of non-farm rural businesses [13]. Kim and Orazem conclude that broadband access has a positive impact on firm location decisions in rural areas [14]. Kolko also finds a positive impact of broadband on local economic growth [15]. Sosa concludes that gigabit broadband contributes even more to GDP growth in communities where it is adopted [16]. Lobo et al. provide multiplier impacts of broadband investments [17]. We use these and other sources to estimate the potential contribution of rural broadband access to rural economic growth and development.

Entrepreneurship and startup activities also are influenced by local infrastructure. Audretsch et al. conclude that broadband access is more important than traditional infrastructure such as railroads and highways [18] in startup activity.

Farm income changes

One can imagine a myriad of ways in which rural broadband access would lead to increased farm profitability – easier communications with suppliers and market outlets, access to Extension and other farm practice information, quicker access to weather information that could impact management decisions and generally improved farm management practices. Kandilov et al. conclude that increased rural broadband access could lead to a six percent increase in farm revenue [19].

Civic engagement

One of the unique features of broadband is that it enables people to connect and collaborate with others in ways that are more cost effective and efficient than alternatives. Whitacre and Manlove conclude that rural broadband adoption is the most influential factor in driving a range of civic engagement metrics [20]. Stern et al. determine that rural broadband access positively influences volunteer activity. Stenberg et al. concluded that broadband availability lowers the costs of civic engagement and community participation. They also note that broadband availability increases community involvement [21]. Rembert et al. indicate that broadband access increased opportunities for participation in civic activities [22].

Property values

Evaluating benefits from increased property values is tricky because any increase in property values could actually be reflecting the value citizens attach to the benefit areas described above. Property values are derived from the stream of value flows including intangibles, such as scenic views. If high speed broadband access is considered as a valuable asset, it could result in an increase in property values, but that increase could mainly reflect the amenity values already covered. Molnar et al. estimate that high speed broadband access would lead to a 3.1 percent increase in housing values, which would represent $5,437 for a median priced home. Generally, property values increase for a number of reasons, but improvement in the incomes and general economic climate in an area certainly are important. For that reason, we conclude that counting both changes in economic benefits and changes in property values would be double counting, so we have not included property value changes in the benefit estimates.

Specific Benefits By Category

Before providing the more detailed description of the analysis being done in this project, we will provide a sort of benchmark based on values from an Ohio study [22]. That study estimates that the annual benefits per connected household is $1,850. In the case of Tipmont, with 22,631 households in its service area and an assumed take rate of 58 percent, there would be 13,126 connected households in year three and a corresponding annual benefit of $24,283,100. While this estimate may be valid, it does not provide any breakdown of the sources of these benefits. We will work through the different kinds of benefits and then return to this aggregate estimate both as a point of comparison and to establish a range of possible benefits.

Telemedicine

The significant benefits of telemedicine are evident in the existing literature. Schadelbauer estimates the economic returns of telehealth to be over $180,000 in annual potential savings per medical facility due to telehealth expansion in rural areas [23]. Grabowski and O'Malley acknowledge the use of telemedicine in reducing hospitalizations of nursing home residents and generating savings for Medicare [24]. The Northeast Regional Alliance program (NERA) is conducting an ongoing multistate research project that is finding that technology that connects aging adults in rural areas with health experts through telemedicine improves physical health through effective diet and activity consultation.

Studies on the economic impact of telemedicine emphasize the cost-savings involved with going virtual for healthcare. Whitacre quantifies the economic impact of telemedicine using site visits to 24 rural hospitals of varying size over a four state area [10]. He finds that telemedicine services contribute between $20,000 to $1.3 million dollars annually to local economies in the United States, with an average of $522,000 per year. A recent published study by Gordon, Adamson, and Devries compares the costs of virtual doctor visits versus in-person visits [24]. They conclude that virtual healthcare appears to be a low cost alternative to healthcare administered in-person. The authors mention that patients are not only using virtual medical services as a first step before seeking in-person care, since there are options to seek further care through virtual services subsequent to their first visit. The caveat mentioned in their study is that adequate resolution must be satisfied for the benefits to be fully realized, due to the need for quality video consultation required to provide these telehealth services.

Online and video consultation are not the only advancements in the field of telehealth. The patient-centered medical home is a model for improving access to healthcare locally and at lower cost, and requires broadband to operate. Rosenberg et al. reveal positive (and cost-effective) results from a patient-centered medical home pilot [25]. These patient-centered medical homes achieved lower medical and pharmacy costs, and more efficient service delivery, such as lower hospital admissions and readmissions, and less use of hospital emergency departments. However, these benefits are not captured in our study, as we focus specifically on telehealth provided either on the home computer or nearby centers that provide telehealth services from specialists far away.

Keeping these categories in mind, this study aims to estimate the benefits of telemedicine specifically for select rural counties neighboring Lafayette, Indiana. We estimate these benefits through translation of past studies to our study area, using appropriate assumptions. Throughout the calculation of benefits for telemedicine, we use the assumption on annual connected households adopted for the entire study period of 20 years. The annual connected households in the Tipmont service territory is outlined in the introduction. We also assume that one person per household per year, would require health services, as a conservative estimate in year one.

The categories for telehealth benefit estimation are presented in the following order:

1. Primary care cost savings from outsourcing procedures
2. Lab/pharmacy work performed locally
3. Reduced use of emergency departments, overnight stays, ambulance services, number of referrals, etc.
4. Initial health consultation via web
5. Transportation savings to center patients
6. Missed work income savings to center patients

The order of benefit categories is strategic in that all benefits arising from the hospital provider side are listed first (benefit categories one to three), followed by all benefits accruing to the patient side (benefit categories four to six). This is important to mention before examining the specifics of each benefit, as we can confidently say there is no double counting of benefits across these categories, as benefits are accruing to different societal stakeholders. Possible double counting within categories, or within the provider or patient side separately, are addressed within each category.

1. Primary care cost savings from outsourcing procedures

For this category we use the study conducted by Gordon, Adamson, and Devries [26]. This study is of particular interest to our analysis as their study area is within Indiana and includes virtual care provided by Anthem through LiveHealth Online. This would likely be the telehealth service that broadband customers would utilize in the Tipmont service area. The authors estimate cost savings of $162 per patient visit at a primary care physician. This number is multiplied by the number of households (and assuming one person per household uses healthcare services per year). This yields benefits of over $2 million in the Tipmont service area - $2,126,409 in year three.

Using the median medical specialists' salary in the United States ($316,000) from Medscape (2017), the Whitacre study approach could be used. Whitacre estimates a reduction of specialist positions from a 1.0 full time position to a 0.2 time position due to telehealth services. One hundred fifty-eight specialists were found from the three surrounding hospitals from the Franciscan Health website (https://www.franciscanhealth.org/find-adoctor?searchtype=all&sortby=fpn&zipcode=47906&radius=25). We assume that the savings would accrue to only one-fourth of the specialists. Multiplying the specialists' median salary by the number of specialists and further multiplying by a factor of one-fifth (reduction to 0.2 time position), yields an annual cost savings of $2,496,400 in year three.

2. Lab/Pharmacy work performed locally

The lab/pharmacy category is guided by the work of Gordon, Adamson, and Devries [26]. The authors find there is a cost savings of 12.56 percent for virtual visit lab rates versus in-person visits. Typical costs for laboratory medical services range from $40 to $2,500 per visit (Blue Shield, 2017). Using the midpoint of this range, $1230, cost reductions of 12.56 percent result in a savings of approximately $148 per laboratory medical service. For all households in the service area, and assuming one person per household visits the lab or pharmacy per year, this amounts to $1,942,645 in year three savings.

Gordon, Adamson, and Devries also state that there is a cost savings of forgone imaging rates, and this savings amounts to 6.62 percent in their study. The average MRI or CAT scan range from $400 to $1,300 (Blue Shield, 2017) and 6.62 percent of the midpoint of $900 is $60 in savings per visit. This is assumed to be MRIs or CAT scans foregone on the average, because telehealth provides other options for the patients. We assume the imaging savings would apply to one-half of the patients. Over all households, this amounts to $393,779 in year three savings.

3. Reduced use of emergency departments, overnight stays, ambulance services, number of referrals, etc.

Gordon, Adamson, and Devries was also used for this category. They estimate cost savings of $1,735 per patient visit at emergency departments, including overnight savings, ambulance services and number of referrals performed. This would be the cost savings by foregoing use of these services due to a patient substitution in behavior towards the use of telehealth services as an alternative. The Centers for Disease Control and Prevention (CDC) provides an estimate of number of emergency department visits per 100 persons per year in the United States. The most recent data found was in the National Hospital Ambulatory Medical Care Survey: 2014 Emergency Department Summary Tables (https://www.cdc.gov/nchs/data/nhamcs/web_tables/2014_ed_web_tables.pdf). The survey sampled a portion of the population and extrapolated those findings to reveal a national average of 45.1 emergency department visits per 100 persons per year (45.1 percent of the population). As the total number of households (including the take rate) in the Tipmont area is 13,126, and assuming there is an average of two people per household, there are an estimated 26,252 people in the Tipmont service area and 45.1 percent of this value is 11,840. Dividing this number by the total number of households, 90.2 percent of the Tipmont service area would utilize the emergency room in the span of a year.

Further, we reduce this multiplier value (90.2 percent) in half, as urgent care clinics are increasingly being used as a substitute for emergency departments (depending on the severity of the condition), and the benefits of urgent care clinics have already been established in benefit category number four. To avoid any double counting of benefits this may bring, we assume only 0.451 (half of 0.902) of the Tipmont households would utilize the emergency services (including overnight stays, ambulance services, and number of referrals) in a year period. The cost savings of $1,735 per patient visit are reduced to yield $10,270,882 in year three savings. These numbers include medical and pharmacy costs involved with emergency department stays.

4. Initial health consultation via web

Once again drawing on the research of Gordon, Adamson, and Devries, they estimate that the cost savings in this category is approximately $36 per patient visit at retail health clinics. This initial health consultation would be the first point of contact with the healthcare system over a home computer (this could be to consult a physician about a physical injury, or it could be the first point of contact when a patient is feeling ill and eventually requires a prescription). Over all households in the service area, and assuming one person per household uses these services per year, $472,535 of savings is estimated for year three.

Gordon, Adamson, and Devries also reveal the cost savings of $153 per visit for urgent care clinics, as opposed to retail health clinics. Over all households, this is $2,008,275 in yearly savings.

5. Transportation savings to center patients

For this calculation, the average distance to the three hospitals in the Tipmont service area are required. The three hospitals are Franciscan Health (FH) centers: FH Crawfordsville, FH Lafayette East and FH Lafayette Central. Using the data on individual distances of each household to the closest of these three hospitals, an average is calculated for mean distance to each hospital, as seen in Table 4. Further, the average distance for all households to all three hospitals was then calculated.

The Internal Revenue Service (IRS) mileage rate is 53.5 cents per mile. Multiplying this by the average distance of 8.85 miles, and further multiplying by the number of households yields the cost savings of foregoing travel to a healthcare facility. This totals $62,148 in year three. It is important to note that this calculation is performed for in-home telemedicine. What can currently be more common is for patients to drive to their nearest hospital and use the teleconferencing equipment there to consult with a specialist in an urban center, who would otherwise be one to three hours away by car. Therefore, the savings would be different in this instance, and would only be for the proportion of the population requiring the needs of a specialist. For this reason, the transportation savings calculation performed here can be considered a conservative baseline estimate, as it does not take into account the forgone one to three hour drive to see a specialist in a specific urban center.

Table 4. Average distances to each of the three hospitals in the Tipmont service area

Hospital	Average Distance
Franciscan Health Crawfordsville	13.17 miles
Franciscan Health Lafayette East	6.50 miles
Franciscan Health Lafayette Central	6.88 miles
Average	**8.85 miles**

6. Missed work income savings to center patients

The missed work income from attending medical appointments in-person is calculated using the estimated time to drive to the appointment/health service and spend time at the appointment/health service.

The estimated time to drive was calculated using the average distance to hospitals, calculated above, divided by an assumption of 40 miles per hour on rural roads. This yielded an average of 0.44 hours driving time (0.22 x 2, for travel to and from), plus an hourlong appointment was assumed, including waiting time to see the healthcare provider.

The average hourly wage rate is then calculated from Tipmont demographic data for their service area. Table 1 above provides the demographic data used to find an average household salary of $73,092. This calculation is performed taking the number of households in each category and multiplying by the midpoint of each income category, shown in the far left column. The first and last categories do not provide a range, so $15,000 and $125,000 are used for the first and last columns, respectively. An average is then calculated of all households in all income categories for the Tipmont service area.

The estimated time to drive to and from the medical service, plus appointment time, is multiplied by the average hourly wage rate for households in the Tipmont service area, using the average salary explained above (assuming 37.5 hours a week multiplied by 50 weeks worked in a year). Over all households in the service area, $736,777 of work hours are used to attend medical appointments and services in a year. This is viewed as the cost savings of telemedicine.

Calculation:

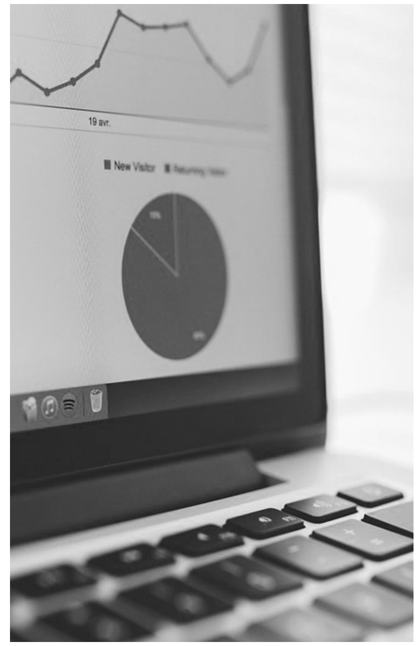
Full Equation: Estimated time to drive + 1 hour appointment x hourly wage rate x number of households

$$\textit{Hourly wage rate: } \frac{73{,}092}{(37.5 \text{ per week x } 50 \text{ weeks})} = \textit{38.98/hour}$$

(8.85 miles / 40 mph = 0.22 hours) x 2 + 1 hour appointment = 1.44 hour appointment x $38.98/hour x 13,126 households = $736,777 in value of work hours saved in year three

Overall Benefits of Telemedicine

The total value of benefits is $20,509,851 in year three, as seen in Table A5 in the Annex. Similar to prior literature on telemedicine, this study reveals large benefits arising from the use of quality broadband to rural areas for medical purposes. A key caveat is that we may have some duplication in these numbers across categories. Examples of where this may occur have been stated within each category above, such as in the reduced use of emergency rooms category. Conversely, there may be other unrealized benefits to both patients and providers not included here. Examples of this are the patient centered medical home, as well as the benefits from connecting with any medical specialist anywhere in the world through broadband access. Nonetheless, this work provides a good structure of the analysis and a good estimate for the aggregate benefits of telemedicine to the Tipmont service territory.



Education

Education is an area for which it is clear that there would be economic and social benefits, but they are very difficult to quantify. For children enrolled in K-12, the web is increasingly being used by teachers for homework, extra practice exercises, etc. There is also a longer term benefit that as broadband becomes more widely available, the whole approach to primary and secondary education is likely to evolve and become more efficient [6]. But what are the efficiencies worth in dollar terms? The Organization for Economic Cooperation and Development (OECD) conducted a study estimating the links between educational attainment and economic growth [27]. Their study was done at the national level, but it is clear that there is a strong and powerful link between educational attainment and economic success. In fact, the study produced estimates of up to $200 trillion over the next 80 years with substantially improved educational attainment in OECD countries. A report from the U.S. Chamber of Commerce provides a good description of the kinds of benefits that broadband brings to K-12 education:

- Increases the number of learning environments
- Enhances educational opportunities for disabled students
- More interactive and personalized instruction
- Enhances learning outcomes
- Promotes the development of 21st century skills

While the study does not quantify the value of these advantages in dollar terms, it does provide multiple case studies and examples of how broadband changes and improves educational attainment. Following is a description of enhanced learning outcomes, Studies have consistently found that Internet-based technologies and tools enhance learning outcomes. For example, a 2002 study found that, in households with broadband connections, "children ages six to 17 reported that high-speed access affected both their online and offline activities, including schoolwork." According to this study, since getting broadband, 66 percent of participating children spent more time online, 36 percent watched less TV, and 23 percent [improved their] grades." Moreover, a recent report by the U.S. Department of Education concluded that, "on average, students in online learning conditions performed better than those receiving face-to-face instruction." Additional studies have found similarly positive impacts of Internet usage on student achievement in reading, literacy, mathematics, and science.[28]

K-12 education benefits have both public good and private good aspects. Of course the households connected to the broadband would see benefits directly for their children as described above. In addition, there would be spillover benefits that would accrue to other children as teachers became more likely to use web based enhanced educational opportunities. Given this blend of public and private benefits, we decided to use a blended benefit estimation approach. For the public benefits and absent prior estimates of the value of all the attributes described above, we decided to assume a productivity increase based on education expenses for teacher salaries and benefits. In the Tippecanoe County School district, by far the largest part of the Tipmont service area (15,460 of 19,870 surveyed households), the 2016-17 budget for K-12 teacher salaries and benefits was $50,987,789. We assume that salary base would grow two percent real over time. Given all the benefits ascribed to broadband in education, we believe it is entirely reasonable to assume a five percent improvement in the teacher function. In early years, the benefit would be scaled by the fraction of households compared with the assumed 58 percent take rate. To assure that at least the direct private benefits to connected customers were included, we multiplied the connected customer number each year by an assumed $365/year ($1/day) educational enhancement benefit. We then took the lower of these two values as the benefit that would be applied each year. The estimated benefit in year three is $1,538,383.

These estimates are likely to underestimate the true value of broadband access for K-12 education because Tippecanoe is only one of the school districts in the Tipmont service area. In addition, this approach makes the very conservative assumption that the educational value provided by teachers is worth what it costs and no more. We know from all the studies that obtaining a high school diploma pays off many times its cost. The same is true with a college degree. Also, over time, a high penetration of rural broadband likely would significantly change the way instruction is delivered and lead to much higher educational attainment.

The other major area for which broadband is likely to be vital is adult education. Adult education is a rapidly growing segment of the total education market. A good example is Purdue's acquisition of Kaplan, which allows Purdue to be a major player in the distance education market. Without question, continuing education will be an important component of expected job skills in the future. However, there are no estimates we could find of the quantitative value of broadband access for continuing education.

Again, this is an area where we know benefits would occur, but they are hard to quantify. Data collected on 57 percent of Tipmont customers by an external source (see Table 2) indicated that 46 percent had a high school education. Improvement in job skills would likely be greater with broadband access. Distance courses, greater access to job openings, MOOCs, etc. would likely lead to higher levels of educational attainment and consequently more or better paying jobs. The median household income in the Tipmont service area (from its survey data in Table 1) is $73,092. If we assume that one individual in five of those households would either get new jobs or better jobs valued at five percent of household income, then the initial annual benefit would be $9.6 million ($73,092*0.05*13,126*0.20).

Business investment and general economic development

This category of benefits, like some of the others, is one in which most believe there will be significant economic benefits. For example, several authors have estimated increases in business location in rural areas with broadband access. But how can the value of these added investments be quantified? Whitacre et al. estimated the difference in growth in household income between rural counties with and without broadband access. We employ their approach to calculate the estimated direct increases in household income. Lobo, et al. used a multiplier approach to estimate the indirect benefits to the county derived from the investment in broadband facilities. We will also adopt that approach to quantify indirect or multiplier benefits.

Household income increase attributable to broadband access

Whitacre estimates a 1.3 percent 10 year difference in household income for counties adopting and those not adopting broadband [13]. Our original thinking was that this growth in household income was largely independent of the other categories. However, upon further reflection, we decided to take a more conservative approach and assume it is largely included in the adult education category.

Multiplier income from the broadband investment

Another category of income increase for any type of economic investment is what is called multiplier benefits. These benefits essentially derive from the fact that any investment induces spending and income increases elsewhere in the local economy. Multiplier analysis commonly also estimates job increases, both direct and indirect, due to the investment. Since our focus is on evaluation of benefits and costs, we only include the income multipliers in this analysis. Lobo et al. estimated the multiplier impacts of a potential high-speed broadband investment in Hamilton county, Kentucky using the well-established IMPLAN model. The total projected capital investment for the Hamilton county system was $193.67 million, so it is a larger investment than envisioned by Tipmont. This does not really impact our analysis since we simply use the multiplier calculated for the Hamilton county investment. The multiplier in that study is applied to both capital and operating cost. The Hamilton county multiplier for the broadband investment is 1.99. In this type of multiplier analysis, the Tipmont expenditures end up getting counted both as a benefit and as a cost. That is, when Tipmont spends $100 million, that spending becomes income for workers and companies in the region. Furthermore, that income is spent and re-spent so the multiplier is greater than one. Use of multipliers is somewhat controversial. To take a more conservative approach for the base case, we apply the spending and re-spending part of the multiplier (0.99) and not count the Tipmont direct expenditures. The base case reporting in this paper uses the spending and re-spending multiplier of 0.99 and multiplies it by system costs.

Using the Bureau of Economic Affairs RIMS multipliers, the Hudson Institute analysis applies a multiplier for Indiana of 1.3264 [8]. We do sensitivity using that multiplier as well. The overall net benefits section contains results with the full multiplier as a sensitivity case. In either case the multiplier benefits are quite large for the proposed broadband investment.

Consumer savings through broadband

The Ohio report cites one study which claimed consumers saved $9,000 per year in various types of consumer purchases [22] by using broadband. That estimate comes from an advocacy group and likely overstates the consumer savings. However, a study conducted in the United Kingdom by Price Waterhouse Coopers estimates consumers save £560 ($754) per year in insurance, energy, general shopping and for services online [29]. We will apply that value to the annual connected households in the Tipmont area. We consider this to be a more reasonable estimate. We will assume that this value remains constant in real terms over the life of the project, although it is likely to grow. The Hudson Institute report also argues that online shopping savings of all kinds represent a large benefit area. For the U.S. rural broadband penetration already achieved, they put the annual benefit at $1 billion. Our third year consumer savings estimate is $9,896,989.

Farm income changes

While there are numerous papers or notes that refer to farm benefits of broadband access, we found two main studies that delve more deeply into this topic [19, 21]. Both studies discuss ways in which farmers could benefit from broadband access. Stenberg et al. provide a broader perspective on rural broadband benefits including education, telework, telemedicine, etc., so much of their work overlaps benefit categories already included in our analysis [21]. Kandilov, et al. discuss reduced costs of interaction with spatially dispersed market participants. They also mention the fact that internet provides better access to weather and price information, which can help improve management decisions [19]. Moreover, broadband access can facilitate adoption of new technology, facilitate use of GIS software, aerial scouting with drones and more.

This source also describes how good internet access could help farmers increase total revenue – enhancing their ability to find new customers and enabling farmers to get better prices for their outputs. Furthermore, they describe the process of using high-speed internet to help diffuse new management information or technologies. In the quantitative section of their paper, they estimate that farmers are able to realize increases in sales of about 19 percent over a seven year period, while farm expenses expand approximately 10 percent over that same period. If we take the difference, the increase is a little over one percent per year. This applies to counties near metropolitan areas. More remote counties distant from a metropolitan center do not realize the benefits. However, Tipmont is adjacent to metropolitan areas, so the quantitative estimates would apply. The fact that sales increased more than expenses implies that output or at least the value of output increased due to broadband access. However, there were statistical problems in this study in determining the change in net profit, because some farms in the study area had negative profit for some years. Also, the further analysis showed that the increase in sales and profits was mainly due to crop activities, not livestock.

In Tippecanoe county which represents the largest share of the Tipmont service area, agricultural crop sales in 2012 were $132,619,000 [30]. One approach would be to use the implied profit increase of one percent and scale it using participation as we did for K-12 education benefits and also limiting the applicability to 50 percent of farm sales. As for K-12, we also included a minimum benefit in this case of $500 a year per connected household. And as for K-12 we took the lower of these two values as the applicable benefit each year. The year three benefit is $663,095.

Civic engagement

There are two important studies that examine the impact of broadband access on civic engagement [20, 31]. The Stern et al. study examines the role of broadband in development and use of rural social networks and in stimulating volunteer activity. They find that rural broadband had positive impacts on social networking and community involvement. No estimates of the economic value of that benefit are developed. Whitacre and Manlove find that adoption of broadband is the most influential of the factors they examined in stimulating civic engagement. Their study represents a quantitative assessment of the key drivers of civic engagement in rural areas. However, again, they make no attempt to quantify the value of the civic engagement benefits.

Thus, while we have no doubt that there would be important civic engagement benefits of a well connected populace; we have no basis for estimating the value of these benefits.

System Costs

All of the cost data were provided to the Purdue research team by the Tipmont REMC. They performed detailed engineering estimations of both capital and operating costs of the system. Table 5 summarizes the capital costs. Three of the capital cost categories vary depending on the take rate. In this analysis we are assuming a price of $60 and a take rate of 58 percent. However, there is also an assumed small membership growth, which increases the mature level of customers as a fraction of initial membership to 61.1 percent. Therefore, those categories are adjusted based on that rate, and the revised capital cost is $105,792,832. We assumed it would all be incurred in year one, although it is possible it might spill over into year two.

Table 5. Tipmont estimated broadband capital costs

		Adjusted
Capital Cost	Amount ($)	Amount
Distribution Fiber	86,080,296	86,080,296
Core Network	1,625,000	1,625,000
Substation Electronics*	4,561,405	2,787,674
Drop Installation*	12,359,200	7,553,248
Subscriber Electronics*	12,675,600	7,746,614
Total Build Capital Cost	117,301,501	105,792,832

*Based on 100 percent take rate

There are nine different categories of operating cost for the system, and they are explained in Table 6. Several of the operating cost categories depend on number of customers opting for broadband. We used the take rate assumptions from Tipmont for years one to three, which are 14.5 percent, 37.7 percent and 58 percent, respectively. In other words, the full anticipated take rate at a fee of $60 per month is reached in year three. However, we assumed a small growth in the customer base of 0.75 percent per year such that the customer base goes from 22,631 to 23,846 in year 10 and remains constant at that rate afterwards. The take rate remains 58 percent of customer base. Table A2 in the Annex provides the operating cost estimates for each of the assumed 20 years in the analysis.

Table 6. Tipmont estimated operating costs for broadband system

Category	Explanation
Fixed	There are many components of fixed operating cost, but we have aggregated them for this analysis.
Labor	Labor costs were estimated for years one to 10 and are projected to remain constant in real terms after that.
Tax	Tax is estimated as 1.4 percent of customer revenue each year, which is $60 times the number of subscribers that year.
New subscribers	$12 for each new subscriber
Billing	$0.65/subscriber/month or $7.80/subscriber/year
Churn	Four percent of subscribers times $200
Bad debt	One percent of revenue
Marketing	$100,000 in year one plus (30, 25, 15, 10, 10, 7.50) per new subscriber. The value re-mains at $7.50 per new subscriber after year six.
Access fee	The access fee is a large component of total operating cost. For years one to three, the monthly fees per customer are $15.68, $20.70, and $22.23. For years four to 20 the monthly fees range from $25.91 to $27.01 depending on the year.

Table 7. Tipmont broadband benefits by category

Item	Net present values
Capital cost	99,804,558
Operating cost	89,613,882
Total cost	189,418,440
Telemedicine	
Primary care savings	22,977,791
Specialist	28,633,511
Transport	671,568
Missed Work	7,961,549
Pharmacy	20,992,056
Imaging	4,255,146
Web consultation	5,106,176
Urgent care	21,701,247
Emergency care	110,986,276
Total telemedicine	223,285,320
K-12 education	18,981,795
Adult education	103,672,388
Multiplier impacts	187,524,256
Consumer savings	106,946,014
Farm income increase	7,165,348
System revenue	102,123,515
Total benefits	**749,698,635**
Net benefits	**560,280,195**

Characterization of Overall Tipmont Broadband Net Benefits

In this section, we summarize the calculation of net benefits and present the overall study results. Table 7 contains the net present value (NPV) of broadband benefits by category. Annual benefit and cost flows are contained in appendix table A1. Appendices tables A3 and A4 provide detailed annual estimates for the telemedicine and other categories, respectively. The total present value of net benefits (benefits after all costs are deducted) is $560 million. The benefit-cost ratio is 3.96, meaning that approximately $4 is returned to the economy for each dollar expended. For reasons stated earlier in this report, we believe this to be a conservative estimate. These benefits can be expressed in different ways. For example, the annualized net benefit is $48,847,781. In other words, the net benefit can be seen as an annual flow of almost $50 million to the Tipmont service area. Alternatively, we can divide the total net present value by the number of Tipmont customers to produce a per customer NPV of $24,757. On an annualized basis, this amounts to an annual net benefit per customer of $2,158. Another metric that could be used is to deduct NPV of Tipmont revenues from the NPV of benefits and then divide that number by the NPV of revenues. That ratio is 4.5 and represents the ratio of benefits received per dollar spent by Tipmont customers. Detailed benefit and cost flows for the 20 year period are provided in the annex.

Yet another indicator that emerges from the analysis is the projected revenue to Tipmont from customers as a fraction of total expected costs over the 20-year period. The ratio of NPV revenue divided by NPV total costs is 0.54. This result highlights the fact that many of the benefits accrue to the local economy and not to the broadband provider. Thus, this is a clear example of a case for which public support will be needed to achieve the high level of public benefits possible from the broadband investment.

While there is uncertainty in any of the benefit estimates, the category that merits special attention for sensitivity analysis is the multiplier impacts. Table 8 provides sensitivity analysis for the multiplier impact analysis. As indicated above, the base case multiplier is 0.99. Table 8 provides multiplier impacts, total NPV and benefit-cost ratios for 1.32 and 1.99 as well.

Table 8. Sensitivity analysis on multiplier impacts

Multiplier value	NPV Multiplier Impact	Total NPV	Benefit-cost ratio
0.99	187,524,256	560,280,195	3.96
1.32	250,032,341	622,788,280	4.29
1.99	376,942,696	749,698,635	4.96

Conclusions

The bottom line conclusion is that investing in rural broadband provides benefits that far exceed the costs. For every dollar Tipmont spends in developing and operating the system, approximately $4 is returned to the economy of the region. There should be no doubt that public sector support for this investment is warranted.

ANNEX

Table A1: Benefit-cost summary over 20 years (current $USD)

Year	Total Cost	Total Telemedicine	Education K-12	Adult	Multiplier	Consumer Savings	Farm Income	Revenue	Total Benefit	Net Benefit
1	109,304,470	6,999,763	369,661	2,398,510	108,211,425	2,474,247	165,774	2,362,676	122,982,057	13,704,111
2	6,027,211	14,205,143	980,342	6,236,127	5,966,939	6,433,043	431,012	6,142,959	40,395,564	34,437,315
3	7,536,349	20,509,851	1,538,383	9,594,041	7,460,986	9,896,989	663,095	9,450,706	59,114,051	51,683,797
4	8,241,184	20,644,952	1,580,919	9,665,997	8,158,773	9,971,216	668,068	9,521,586	60,211,511	52,077,218
5	8,418,913	20,781,066	1,624,632	9,738,492	8,334,724	10,046,000	673,079	9,592,998	60,790,991	52,479,770
6	8,351,882	20,918,201	1,669,553	9,811,530	8,268,364	10,121,345	678,127	9,664,945	61,132,066	52,888,683
7	8,355,206	21,056,365	1,715,716	9,885,117	8,271,654	10,197,256	683,213	9,737,432	61,546,752	53,300,860
8	8,462,295	21,195,564	1,763,156	9,959,255	8,377,672	10,273,735	688,337	9,810,463	62,068,182	53,716,021
9	8,445,152	21,335,808	1,811,907	10,033,950	8,360,701	10,350,788	693,499	9,884,042	62,470,694	54,136,502
10	8,536,331	21,477,104	1,862,006	10,109,204	8,450,968	10,428,419	698,701	9,958,172	62,984,573	54,560,034
11	8,572,962	21,477,104	1,899,246	10,109,204	8,487,232	10,428,419	698,701	9,958,172	63,058,078	54,596,908
12	8,588,716	21,477,104	1,937,231	10,109,204	8,502,829	10,428,419	698,701	9,958,172	63,111,659	54,634,735
13	8,579,006	21,477,104	1,975,976	10,109,204	8,493,216	10,428,419	698,701	9,958,172	63,140,791	54,673,577
14	8,553,324	21,477,104	2,015,495	10,109,204	8,467,791	10,428,419	698,701	9,958,172	63,154,885	54,713,353
15	8,562,016	21,477,104	2,055,805	10,109,204	8,476,396	10,428,419	698,701	9,958,172	63,203,800	54,753,576
16	8,557,044	21,477,104	2,096,921	10,109,204	8,471,474	10,428,419	698,701	9,958,172	63,239,995	54,794,742
17	8,546,387	21,477,104	2,138,860	10,109,204	8,460,923	10,428,419	698,701	9,958,172	63,271,382	54,836,787
18	8,602,889	21,477,104	2,181,637	10,109,204	8,516,860	10,428,419	698,701	9,958,172	63,370,096	54,878,999
19	8,640,094	21,477,104	2,225,270	10,109,204	8,553,693	10,428,419	698,701	9,958,172	63,450,562	54,922,260
20	8,649,176	21,477,104	2,269,775	10,109,204	8,562,685	10,428,419	698,701	9,958,172	63,504,059	54,966,675
NPV	189,418,440	223,285,320	18,981,795	103,672,388	187,524,256	106,946,014	7,165,348	102,123,515	749,698,635	560,280,195
								Net benefit per member		24,757
								Benefit-cost ratio		3.96

Table A2: Operating costs for broadband adoption in the Tipmont service area over 20 years (current $USD)

Year	Fixed	Labor	Subscribers	Revenue	Tax	New Sub.	Billing	Churn	Bad Debt	Marketing	Access Fee	Total
1	868,549	1,098,750	3,281	2,362,676	33,077	39,378	25,596	26,252	23,627	778,930	617,479	3,511,638
2	1,155,455	1,841,250	8,532	6,142,959	86,001	63,005	66,549	68,255	61,430	565,775	2,119,491	6,027,211
3	1,190,205	2,016,250	13,126	9,450,706	132,310	55,129	102,383	105,008	94,507	339,465	3,501,093	7,536,349
4	1,165,070	2,122,500	13,224	9,521,586	133,302	1,181	103,151	105,795	95,216	228,007	4,286,962	8,241,184
5	1,210,562	2,242,500	13,324	9,592,998	134,302	1,190	103,924	106,589	95,930	229,717	4,294,199	8,418,913
6	1,189,115	2,242,500	13,424	9,664,945	135,309	1,199	104,704	107,388	96,649	173,580	4,301,438	8,351,882
7	1,193,269	2,242,500	13,524	9,737,432	136,324	1,208	105,489	108,194	97,374	174,882	4,295,966	8,355,206
8	1,229,197	2,325,000	13,626	9,810,463	137,346	1,217	106,280	109,005	98,105	176,194	4,279,951	8,462,295
9	1,218,898	2,325,000	13,728	9,884,042	138,377	1,226	107,077	109,823	98,840	177,515	4,268,396	8,445,152
10	1,210,249	2,325,000	13,831	9,958,172	139,414	1,236	107,880	110,646	99,582	178,846	4,363,477	8,536,331
11	1,213,815	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,397,778	8,572,962
12	1,215,738	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,411,608	8,588,716
13	1,219,444	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,398,193	8,579,006
14	1,223,222	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,368,733	8,553,324
15	1,227,073	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,373,574	8,562,016
16	1,232,890	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,362,786	8,557,044
17	1,236,892	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,348,125	8,546,387
18	1,246,370	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,395,150	8,602,889
19	1,248,030	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,430,695	8,640,094
20	1,252,271	2,325,000	13,831	9,958,172	139,414	0	107,880	110,646	99,582	178,846	4,435,536	8,649,176

Table A3: Telemedicine benefits over 20 years (current $USD)

Year	Primary Savings	Specialist	Transport	Missed Work	Pharmacy	Imaging	Web Consult	Urgent	Emergency	Total
1	531,602	2,496,400	15,537	184,194	485,661	98,445	118,134	502,069	2,567,721	6,999,763
2	1,382,166	2,496,400	40,396	478,905	1,262,719	255,957	307,148	1,305,379	6,676,074	14,205,143
3	2,126,409	2,496,400	62,148	736,777	1,942,645	393,779	472,535	2,008,275	10,270,882	20,509,851
4	2,142,357	2,496,400	62,614	742,303	1,957,215	396,733	476,079	2,023,337	10,347,914	20,644,952
5	2,158,425	2,496,400	63,084	747,870	1,971,894	399,708	479,650	2,038,512	10,425,523	20,781,066
6	2,174,613	2,496,400	63,557	753,479	1,986,683	402,706	483,247	2,053,801	10,503,715	20,918,201
7	2,190,922	2,496,400	64,034	759,130	2,001,583	405,726	486,872	2,069,204	10,582,493	21,056,365
8	2,207,354	2,496,400	64,514	764,824	2,016,595	408,769	490,523	2,084,723	10,661,861	21,195,564
9	2,223,909	2,496,400	64,998	770,560	2,031,720	411,835	494,202	2,100,359	10,741,825	21,335,808
10	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
11	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
12	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
13	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
14	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
15	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
16	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
17	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
18	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
19	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
20	2,240,589	2,496,400	65,485	776,339	2,046,958	414,924	497,909	2,116,112	10,822,389	21,477,104
NPV	22,977,791	28,633,511	671,568	7,961,549	20,992,056	4,255,146	5,106,176	21,701,247	110,986,276	223,285,320

Table A4: Other benefits over 20 years (current $USD)

Year	Education K-12	Adult	Multiplier	Consumer Savings	Farm Income	Revenue
1	369,661	2,398,510	108,211,425	2,474,247	165,774	2,362,676
2	980,342	6,236,127	5,966,939	6,433,043	431,012	6,142,959
3	1,538,383	9,594,041	7,460,986	9,896,989	663,095	9,450,706
4	1,580,919	9,665,997	8,158,773	9,971,216	668,068	9,521,586
5	1,624,632	9,738,492	8,334,724	10,046,000	673,079	9,592,998
6	1,669,553	9,811,530	8,268,364	10,121,345	678,127	9,664,945
7	1,715,716	9,885,117	8,271,654	10,197,256	683,213	9,737,432
8	1,763,156	9,959,255	8,377,672	10,273,735	688,337	9,810,463
9	1,811,907	10,033,950	8,360,701	10,350,788	693,499	9,884,042
10	1,862,006	10,109,204	8,450,968	10,428,419	698,701	9,958,172
11	1,899,246	10,109,204	8,487,232	10,428,419	698,701	9,958,172
12	1,937,231	10,109,204	8,502,829	10,428,419	698,701	9,958,172
13	1,975,976	10,109,204	8,493,216	10,428,419	698,701	9,958,172
14	2,015,495	10,109,204	8,467,791	10,428,419	698,701	9,958,172
15	2,055,805	10,109,204	8,476,396	10,428,419	698,701	9,958,172
16	2,096,921	10,109,204	8,471,474	10,428,419	698,701	9,958,172
17	2,138,860	10,109,204	8,460,923	10,428,419	698,701	9,958,172
18	2,181,637	10,109,204	8,516,860	10,428,419	698,701	9,958,172
19	2,225,270	10,109,204	8,553,693	10,428,419	698,701	9,958,172
20	2,269,775	10,109,204	8,562,685	10,428,419	698,701	9,958,172
NPV	18,981,795	103,672,388	187,524,256	106,946,014	7,165,348	102,123,515

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