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Internet-Based Economic Development For Rural Communities

Dr. Jo Min
Balaji Sukhumaran
Siju Varghese

Iowa State University

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Jo Min, Ph.D.
Principal Investigator

Balaji Sukhumaran
Siju Varghese
Research Assistants

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Industrial and Manufacturing Systems Engineering
Iowa State University
2019, Black Engineering,
Ames, Iowa 50014
(515) 294 8095
jomin@iastate.edu

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EXECUTIVE SUMMARY

In recent years, Internet activities that can be performed in rural communities have been greatly expanded due to the broadband technology that enables exchanges of a large amount of data at high speed. On the other hand, considering the complexity of the technology and the time and money involved in the deployment of the technology, it is highly desirable for economic development practitioners and policy makers to review various aspects of broadband technology deployment in rural communities.

Under these circumstances, in this report we comprehensively investigate economic development via the Internet in rural communities based on available published information. Specifically, we first examine the economic opportunities in rural communities that are feasible through broadband deployment. Next, we introduce and compare various technology options in broadband deployment and their advantages or disadvantages. This is followed by a study of various key issues in broadband deployment such as the open access policy.

Once the basic issues on the economic opportunities in rural communities and the technology options are addressed, we proceed to discuss how broadband deployment options can be objectively and quantitatively evaluated for adoption. Specifically, we first review fundamental factors and methods for evaluation. Next, we examine in detail quantitative methods such as the net present value method for a single criterion evaluation and the analytic hierarchical process method for multiple criteria evaluation. Such quantitative models can be useful to practitioners for decision support purposes.

We then investigate relevant current practices in rural communities, which can help practitioners appreciate the successes and failures of the broadband deployment currently carried out. Finally, for practitioners, we present a list of knowledge requirements for successful broadband deployment and other policy implications.

Given the economic opportunities, technology options, decision support models, case studies, numerous examples, key debate issues, and policy implications described in this report, we strongly believe that the readers and practitioners will appreciate better the potential benefits as well as the complexity and risk of broadband deployment for rural economic development. Also, we strongly hope that such appreciation will lead to better preparation of readers and practitioners for this immensely important technology deployment task.

1. INTRODUCTION

In this report, we examine how broadband technology can assist the economic development of rural communities. Specifically, based on published books, journals and trade magazines as well as on Internet sites, we investigate characteristics of rural communities and technological options. Also, we study the current practices as well as the key debates. Finally, based on the best information available, we propose a couple of decision support models and discuss the policy implications of rural economic development via the Internet. In the rest of this section, we explain the circumstances and background of Internet technologies and rural communities.

The rural communities are much interested in economic development as it can lead to improved standard of living through job creation, higher income, better education, healthcare, and additional social services. Of various technologies that can assist economic development, telecommunication plays a vital role. Excellent telecommunication services in the community will enhance the competitiveness of local enterprises, enable them to cooperate with similar enterprises in different locations, and attract more businesses to the community.

With the advent of the Internet, the importance of telecommunication has become more pronounced. The Internet has made it possible to swap digitized information with more speed, ease, and convenience. Messages sent via the Internet Protocol (IP) primarily e-mail—are increasingly replacing traditional telephone and fax communication [1]. High-speed Internet or broadband technology will continue to drive the Internet to substitute for older forms of communication.

In general, broadband or high-speed Internet access is the ability to send and receive data at volumes and speeds far greater than current Internet access over traditional telephone lines. In addition to offering speed, broadband access provides a continuous, "always on" connection (no need to dial-up) and a "two-way" capability, that is, the ability to both receive (download) and transmit (upload) data at high speeds. With the broadband technology, many government and business activities that require exchanges of a large amount of data, such as telemedicine and e-commerce, are now feasible for rural communities.

From an economic development perspective, broadband technology could be a break-through for a rural community. However, broadband technology is complex, and the deployment of such technology requires a huge investment of money and time [2]. The reason for the complexity is the large number of technological options available in broadband. Therefore, we will examine various aspects of broadband technology deployment such as technical options, key debates, and case studies to derive policy implications for economic development practitioners.

The wide variety of choices available today makes it difficult for the economic development practitioners to make the right decision with confidence. From their standpoint, a more quantitative methodology is highly desirable in order to evaluate the options available. This problem is more serious when the resources available for the implementation of these technologies are not abundant. In rural areas the capital required for investment in new technologies for economic development is relatively small. There is also very little room for failure when deciding on strategies for economic development in rural areas.

The various technologies can be categorized into conventional wire line (Digital Subscriber Line (DSL), cable modem), wireless technology and other advanced technology (fiber optics, etc.). By conventional wire line, we mean that copper wires may be included. While by other advanced technology, we mean only fiber optics cables are included. Each of these has unique characteristics associated with it. This makes them feasible for some applications while infeasible for others. Economic development practitioners have to decide on which technology given the limitations of resources and time.

An example can be seen city of Austin, Texas [3], where the city officials used consultants in deciding the best technology to deploy. A trade-off was made between providing the latest all fiber networks and the Hybrid Fiber Co-axial (HFC) network, which is relatively old compared to all fiber networks. The subscribers living close to the backbone were provided all fiber solutions whereas the ones living far off were given the HFC technology to reduce cost of installation and deployment. Here we see a clear-cut decision making process involved in choosing the right technology from the available technologies.

These investments are greatly affected by the policies that are prevalent in this industry. In the above example, cable modem was used as the solution but no reference has been made to the debates currently taking place for cable modem such as open access policies, which allow the subscribers using cable modem to use the Internet Service Provider (ISP) of their choice [4]. Also other issues of importance are the determination of the service provider for broadband technology and availability of funding for investment in new technology [5] and [6].

In the following sections we will address the various issues mentioned above. We hope that economic development practitioners and policy makers will benefit from the examination of the various aspects of the broadband technology deployment, and the report will serve as a basis for further studies in this important economic development issue in rural communities.

2. OVERVIEW OF INTERNET-BASED ECONOMIC DEVELOPMENT IN RURAL COMMUNITIES

Recently, there have been numerous attempts to develop Internet infrastructure in rural communities. A primary reason for such attempts is that the potential for economic development via the Internet is quite substantial. In this section, we will first introduce economic development via the Internet in rural communities. Next, we will examine businesses that can take advantage of the Internet for economic development.

2.1 Economic Development via the Internet

Rural communities are often characterized by relatively long distances from urban communities and a high degree of locational isolation. In addition, they are often characterized by low population density and meager economic infrastructure. These conditions, in turn, have led to a declining number of jobs and migration to urban communities, which makes the economic development of rural communities a major challenge to economic development practitioners and policy makers.

However, with advances in telecommunication technology, especially with the growth of the Internet and the introduction of broadband technology, distance is much less a barrier for economic development in rural communities. For example, with well-planned infrastructure for broadband service, rural communities can be competitive in attracting businesses. In fact, with broadband service, businesses such as telemedicine, electronic commerce and back-office functions may find it advantageous to locate in rural communities. Also, with broadband service, traditional industries, such as manufacturing, may find it less compelling to locate in urban communities.

Considering the number of businesses to benefit, as well as the kinds of businesses, broadband service should be critical in the economic development of rural communities. On the other hand, there are quite a few technological choices available for broadband deployment (see section 3 for detail). This makes it important and difficult to determine the optimal choice of technology for broadband deployment. Nonetheless, economic development practitioners and policy makers must fully consider the target businesses to be attracted and the kinds of broadband infrastructure the target businesses need, and make an informed decision on the optimal infrastructure for rural community.

An example of broadband deployment is the case of Kearney, Nebraska [7] Kearney can be viewed as an "intermediate" community in the sense that it is by no means a metropolitan community, but is not a small rural community, either. In Kearney, economic development practitioners decided to attract new businesses to make Kearney's job base more diverse (it had been heavily dependent on a college located in Kearney). An appropriate broadband infrastructure was built. This enabled them to attract a telemarketing firm that would utilize the broadband infrastructure. They also encouraged local firms to take advantage of this new infrastructure. Furthermore, this infrastructure enabled the local college to offer new technology-oriented courses, providing students with more opportunities in hi-tech industries.

This example illustrates the importance of coordinating activities by members of the community for Internet-based economic development. The prerequisite for any such coordination, however, is the knowledge on various businesses that substantially utilize the broadband infrastructure. Hence, we now proceed to examine such businesses in rural communities.

2.2 Businesses via the Internet

Broadband technology provides the options for businesses to operate in rural areas where the operating costs can be much less than those in urban areas [7]. This report compares operating cost for a telemarketing firm in rural and urban area. The figures show that there is a considerable difference in the operating cost for the company operating in a rural area.

According to Kenyon, Jacks and Glaser [7], some of the changes in the way businesses operate with the new technology are,

- Empowering individuals beyond real or imagined limitations of handicaps, sex, locale, etc.
- Enhancing communication between workers.
- Transferring large amounts of data and images over local, or wide area networks.
- Managing funds from remote locations.
- Interacting with each other regardless of distances or sovereignty.

These changes and the low cost of operation makes it possible for rural areas to be a competitive place for new businesses to operate.

For example, service industries find that, it is more profitable for them to operate their back offices in rural areas than in urban areas. Telecommuting (working from satellite offices or homes for one or two days a week) and teleworking (working from home or satellite offices throughout the week) are growing rapidly because of telecommunications capabilities. Online transaction systems, online monitoring systems, EDI (Electronic Data Interchange), and electronic commerce are a few more examples where rural communities can attract businesses by providing an appropriate Internet infrastructure [8]. Back offices provide opportunity for the residents in rural communities to become familiar with new technologies. This will increase their relative technological competence as compared to urban residents.

Some of the types of businesses that broadband deployment in the rural communities may attract are [9], [10], [11], and [12].

- Electronic Commerce
  Electronic Commerce can be defined as any business transaction done over the Internet. The thrust has been more on the business-to-business e-commerce, which has been projected to grow even more than the normal retail e-commerce.

- Government and education services delivery
  Distance education is a way of providing students in rural areas an opportunity to participate on a real time basis in classes far away from their homes. This also provides the students in rural areas with opportunities to interact with the outside world and opportunities to develop and maintain technological competency.

- Telemedicine
  The disparity in the level of medical services available between urban and rural areas can be overcome to a great extent by providing doctors and nurses in rural areas with the capability to interact with physicians and resources in urban areas. In addition, distance education using broadband technology can enhance education, training and support for patients, doctors and nurses. Telemedicine breaks down geographic barriers and can be cost effective by treating patients on numerous remote sites who may not have good access to a comprehensive hospital. We note that there have been substantial increases in interactive telemedicine programs in the United States [13].

We show a few examples where broadband technology may result in substantial economic development for rural communities. However, we note that the dependence of a particular firm on broadband technology can vary according to how many kinds of service it actually provides over the Internet [6].

We now study two additional examples with respect to broadband technology requirements and how broadband technology can bring about economic development in rural communities. These examples are from the telemarketing industry and the hi-tech manufacturing sector.

The telemarketing industry requires numerous calls each day to customers and at the same time accesses data about customers from a central database (which could be located in some remote location). Availability of broadband infrastructure is vital in delivering these services. This is a job intensive industry that can attract more people to rural areas. Since telemarketing uses hi-tech services, it will foster technology-oriented knowledge in rural residents, which will lead to better skills for future employment.

The manufacturing industry has an advantage in relocating plants to rural areas because of the lower operating costs. On the other hand, the scarcity of engineers and designers in rural areas hinders any relocation attempt by the manufacturer. Because the broadband technology can transmit images of designed items from the urban offices to the rural manufacturing facilities instantaneously, manufacturing can be performed on a real time basis. This also will lead to a streamlined process of reducing inventory and manufacturing on demand [62]. For example, the EDI applications have helped textile producers reduce inventories in southern US rural regions [62].

The difference in the magnitude of data transfer for these two industries is that the telemarketing firm requires a large number of telephone lines for contacting customers and retrieving data about customers through online access systems. The manufacturer operations would require huge amounts of data transfer, that could include CAD (computer aided design) images.

We will now look into a few technologies that can be used for these two industries. The latest development of voice over IP allows telephone calls to be made over the Internet and this can substantially reduce the cost of operation for the telemarketing industry. A broadband technology that can deliver these services will be more suited for the telemarketing industry. Hence, if a telemarketing business is being targeted for rural communities, then a broadband technology that can support voice over IP would be a better choice. Furthermore, the ability of the cable modem for supporting multiple calls on a single modem is a plus for such industries. The Com21 cable modem, with the new T-AIM 200, supports up to two phone lines and eight PCs, for simultaneous phone calls and Internet access. Because of its advanced ATM features, the Com21 modem is able to handle multiple independent communication streams.

In the case of the manufacturing, the requirement is to transfer huge files that may contain a few CAD images. This service can be achieved with DSL technology. Furthermore, DSL technology has more options to offer varying speed over distance, which can be considered for the above application (see section 3 for detail).

A few more industries that can be established in rural areas are

- Accounting services
- Advertising agency
- Brokering services
- Consulting services
- Credit bureau agencies [10]

Selecting a few of the above mentioned industries that can be attracted to rural communities, and providing them with appropriate broadband services can help rural communities in their economic development. A detailed analysis of the industries, their operations, and their requirements can be helpful in making an informed decision on optimal selection of the broadband technology. In the next section, we discuss and compare various options in broadband technology, the infrastructure requirements, and their advantages/disadvantages.

3. TECHNOLOGY

In the past, data as well as voice were transmitted over copper wires only as analog signals. In recent years, however, data and voice are being transmitted as digital signals using various media such as the traditional copper wires, new wireless technologies, and fiber optics. This has resulted in fast and accurate transmission of various forms of information (e.g. data, voice, video, audio). More recently, broadband technology has revolutionized the telecommunication industry by providing high speed and large capacity transmission of data and voice to customers. Broadband technology changed the way these services can be provided in an integrated format. In this section, we explain what broadband services are and the major technologies that are available to provide these services.

3.1 Broadband Technology

Broadband technology is the use of a larger frequency spectrum for the transmission of data [14] and [15]. In the past, a small portion of the frequency spectrum was used for transmission. Hence, less data could be transmitted at a given time. Also, in the past, the telephone had to be engaged when the Internet was in use via a dial-up modem, which made the simultaneous use of telephone impossible (i.e. the service is not "integrated"). On the other hand, fiber optic cables (which transmit data using light) for broadband technology have meant a substantial increase in both speed and capacity of transmission.

Broadband makes new services available to users at their homes. Some of these services are on a real time basis. However, the term broadband has to be defined to include the capabilities provided to the customers. The Federal Communications Commission (FCC) defines broadband telecommunication services as the ability to provide Internet access at a minimum speed of 200 kilobits per second in both directions. This speed should be sufficient to provide the transmission of the previously mentioned forms of information over the Internet. Speed becomes far more important when the users are businesses that need advanced connectivity to the Internet to increase revenues. The importance of Internet connectivity has resulted from the emphasis on automating the business process via e-commerce (electronic commerce). Large companies have used faster ways of connecting to the Internet by traditional means such as T1 connection (explained in section 3.2) and have maintained their market share. But small companies, especially ones in rural areas, need to have access to these technologies in an affordable manner. The new broadband technologies can make this possible and can be a major tool for economic development in rural areas.

A traditional Internet connection uses a dial-up modem, which allows the digital signals from the computer to be converted to analog signals, which are transmitted over the telephone network. The highest speed achievable through such systems is 45000 bits per second (bps), using a 56K modem. This is far less than FCC's definition of broadband communication. Also, companies are not comfortable with a dial-up system because they need connection without any disturbances. Users will have their telephone connection blocked during the use of the Internet.

Broadband technology, on the other hand, provides far greater speed and also the ability to have a dedicated connection that does not need dialing the ISP. This also means no phone charge for using the Internet. This is a plus for small companies that do not use the Internet to increase their revenues, but still need the technology.

3.2 Broadband Access Technologies

The problem of providing network solutions is mainly concentrated on the last mile, which is the part of the network that connects the final switching office to the home or office. This is because the backbone infrastructures, which connect the various switching offices, are well installed all over the country. As mentioned in Section 2 there are a number of technologies available to cover the last mile and each has different characteristics. These technologies can be divided basically as

- Conventional Wireline technologies that use copper or fiber as the medium to transmit the signals.
- Wireless technologies that use radio waves to transmit the signals.
- Other advanced technologies with newer configuration such as Fiber-To-The- Home.

It is here that a decision has to be made on the selection of the right technology. Quite a few references are available on the technologies for delivering broadband services. However there are very few references for a methodology for selecting the most suitable technology.

3.2.1 Conventional Wireline Technologies

These require a physically wired connection between the service provider and the customer. The wire is usually copper, which is now often being upgraded to fiber (For fiber, the substantial installation cost may be a problem in rural areas where the potential number of customers may not be sufficient to justify such a large capital investment). The two major competing technologies using wired connection are the DSL and the cable modem.

3.2.1.a DSL

This is a service provided since 1996 by local telephone companies. It allows the transmission of voice and data at the same time, data being transmitted at speed much greater than the minimum broadband speed specified by FCC.

DSL has variations depending upon the speed and the symmetry of transmission. That is, whether the speed of transmission is equal in both directions. These technologies collectively are known as xDSL. ADSL is one of several types of xDSL technologies, which stands for Asymmetric DSL. It is so named because the speed of upstream transmission (i.e. transmission of data from the user side) is less than the speed of downstream transmission (i.e. transmission of data to the user side). ADSL has two main standards: The ADSL–1 specifies a downstream rate of 1.5 or 2 Mbps and an upstream rate of 16 to 64 kbps; ADSL–3 specifies a downstream rate of up to 6.144 Mbps and an upstream channel of up to 640 kbps. Twisted-pair lines with no bridged

taps can support ADSL–1 rate up to 18,000 feet (on a 24-gauge wire), or the ADSL–3 rate up to 12,000 feet. It is claimed that ADSL can be implemented on 70 to 80 percent of the world's nearly 750 million telephone lines [16].

Other variations of the DSL family are the HDSL and SDSL, which stand for High-data-rate DSL and Symmetrical DSL respectively. HDSL modems transmit 1.5 Mbps (megabit per seconds) in each direction. Two twisted pairs of wires are used, with half of the traffic on each pair. A 2.0–Mbps transmission rate is also available, using three pairs of wires (one-third of the traffic on each pair). The wire limit is 12,000 feet (on a 24-gauge wire) or 9000 feet (on a 26-gauge wire). Symmetrical digital subscriber line (SDSL) is similar to HDSL but requires only one pair of wires. Transmission speed ranges from n x 64 kbps (where n is the number of channels) to 2.0 Mbps in both directions. HDSL and SDSL are intended as lower-cost replacements for ISDN or dedicated T1 (explained next) or fractional–T1 lines or T3 lines.

T1 lines were long the standard for industrial use and are in use even today. While a 128K ISDN line is made up of two 64k digital “B” channels, a T1 is basically 23 of those same “B” channels bundled into one loop. So a full T1 line is 1.5Mbps of bandwidth. It is possible for a telephone company to sell a portion of a T1. This lowers the cost of the bandwidth charge, but not the line charge. The equipment that the customer will need for a fractional T1 can also be upgraded to a full T1 at a later date, giving them expandability and more life from the equipment investment. A T3 is actually 45Mbps, which is about 30 times the capacity of a T1. T3s can cost upwards of $20,000/month, and hence may not suited for small businesses. A T3 connection is also usually carried on fiber optic lines, requiring special (expensive) switching equipment.

One advantage of using DSL is that the service for business use can be integrated with the services for residential customers, as there is no security concerns, such as sharing, compared to cable modem. Another advantage of the DSL option is that high-bandwidth Internet service can be provided on the existing copper loop [17]. The future of DSL looks quite bright [18]. It is predicted that DSL will be available to almost 70 percent of U.S. homes by 2004. Hence, DSL provides a substantial opportunity to expand the broadband service via telephone lines.

There are two major disadvantages of the DSL technology.

1. It has a distance limitation for transmission. The signals attenuate as the length of the copper loop from the central office increases [17]. DSL cannot function if the customer is 18000 ft away from the Central Office (CO). This is a major drawback for rural areas because typically less people are spread over a large area with distances often exceeding 18000 ft.
2. DSL cannot work with devices such as loading coils and network bridges that have been used by the rural Telephone companies for providing voice services over long distance. These devices were originally included in the network because the signals dissipate over distance and they provide a way of transmitting the voice for long distance. Since DSL

cannot work with these devices there has to be a major network up-grade, which may be very costly, if it means putting in a new central office.

3.2.1.b Cable Modem

Cable modem is a method of providing Internet access via the cable TV networks. This requires the use of a cable modem that separates the normal cable TV channels from the data channels. Usually the cable TV operators upgrade their cable networks by providing fiber up to a certain hub from the head end (equivalent to a central office) and further distributing the lines from the hub using co-axial copper wires.

Cable TV Hybrid Fiber/Coax (HFC) System
This has only downstream broadcast capability and broadcasts downstream in the 50- to 550/750-MHz band with 6-MHz channels. Cable Modems are used to allow Internet and data transmission in the downstream direction of the HFC system. Internet data speeds up to the 30–Mbps range can be realized in a nominal 6-MHz video channel. An existing telephone channel using VBD (Voice Band Data) or ISDN provides the upstream signal.

Bi-directional HFC system
This newer systems (an up-graded of the HFC system) has transmission capability in both directions. Such bi-directional cable–TV systems typically broadcast downstream in the 50- to 750-MHz bandwidth of coaxial cable within the 6-MHz nominal video channels. The upstream bandwidth is shared among all the homes passed by the coaxial cable and is nominally limited to the 5- to 40-MHz frequency band. Downstream Internet data speed up to the 30-Mbps ranges in 6-MHz channels can be realized. Upstream data is contention based and operates at claimed speed of up to 10 Mbps. In practical multi-user environments, however, actual throughput speeds will be significantly less as the load on the system increases. Cable modems can either be overlaid onto the HFC system or be an integrated part of the HFC system.

Switched Digital Broadband (SDB) Systems
SDB is classified as a baseband digital system with nominal 50-Mbps point-to-point downstream rates that can be apportioned as desired between digital video and data. For data, a 1.5-Mbps nominal, contention-based, upstream data bandwidth is available. Though the system is contention based, there is always a minimum guaranteed upstream data rate available—typically in the order of 16 kbps.

All three architectures described above have provisions for both analog and digital video broadcast capability. Both the bi-directional HFC and SDB systems are broadband systems that are applicable to telephony, video, Internet/data, and PCS wireline access. The architectures have a number of similar characteristics and components. The bi-directional HFC system provides fiber distribution to the fiber node. At the fiber node, signals are collected and distributed to multiple-coax feeds that cover a given residential area. Fiber nodes are designed to serve from 500 to 2000 homes.

SDB systems push fiber closer to the end-user. In typical systems, feeder fiber can be optically split. Optical network units (ONUs) terminate the fiber and provide individual coax (and twisted-pair) drops to subscribers. A typical ONU can serve from 4 to 60 homes. Thus, SDB brings fiber closer to the customer. In many ways, HFC, SDB, and PON (discussed in Subsection 3.2.3) can be viewed as a continuum of technology where fiber moves ever closer to the customer premises.

An advantage of the cable modem option is that high-bandwidth Internet service can be provided on existing cable TV lines. Moreover they also can provide speeds faster than DSL services. Also, an upgraded cable network exhibits a high degree of reliability.

However, there are two major disadvantages of the cable systems:

1. Cable Modems have a shared architecture, which means that a number of users are connected to the same branch. Hence the speed of the network decreases as more subscribers use the system at the same time. This implies that the promised speed cannot be delivered at all time.
2. Since this a shared architecture there is always a problem of security for the business customers [19].

3.2.2 Wireless Technologies

Wireless networks can be of two types. One is fixed wireless and the other is the satellite communication. Both of these provide a solution to remote access issues in rural areas. Most of their technologies are still new and certain concerns (such as bi-directional communication) need to be resolved. The architecture involves connecting the customer's devices to a customer-side antenna that communicates with a provider-side antenna. There are basically three ways of providing wireless Internet access.

- **Cellular**
  Internet access can be provided via existing cellular systems using voice band modems. Because cellular channels may be narrowband, access rates are limited to 9.6 kbps for advanced mobile phone service (AMPS) and time division multiple access (TDMA) systems and to 14.4 kbps for code division multiple access (CDMA) systems. Cellular digital packet data (CDPD) is a technique that enables the data rate of AMPS to be extended to 19.2 kbps. CDPD achieves the higher rate by inserting Internet protocol (IP) packets directly into cellular channels that do not contain voice traffic (i.e., channels that are temporarily idle).

- **Terrestrial Broadcast**
  The multichannel multipoint distribution service (MMDS), sometimes called "wireless cable," can provide Internet-access downlinks over a distance of about 50 km from a central-transmitter site. MMDS downlinks combined with telephony uplinks provide a complete Internet-access arrangement. MMDS operates in the 2-GHz frequency band with 33 channels, each capable of supporting downlink data rates that are currently about 10 Mbps. Technology improvements are expected to increase data rates to 27 Mbps in the future.

Local multipoint distribution service (LMDS) is similar to MMDS in that it will use microwave transmission to provide Internet-access downlinks and wireline telephony to provide uplink access. LMDS will use transmitters operating in the 28-GHz frequency band with each transmitter covering a distance of about 5 km. The relatively close transmitter spacing, coupled with the fact that LMDS will have about four times the bandwidth of MMDS, should enable LMDS to serve a much higher density of Internet users than MMDS. [20].

- **Satellite Broadcast**
  Several approaches have been proposed for using satellites to provide Internet-access downlinks. Some proposals are based on using a single fixed-position satellite, whereas others would use clusters of satellites. Proposed data rates vary from low-speed, single-user channels to shared channels with rates greater than one Mbps.

  The first widely available system operates in the 12-GHz band and uses a data rate of 400 kbps. Equipment at the end-user location consists of a dish antenna, approximately 52 cm in diameter, a microwave receiver, and a digital decoder card that plugs directly into a PC computer bus. Satellite systems also use telephone circuits for uplink access.

  One technology that was investigated is the very small aperture terminal (VSAT) technology [21]. It is distance independent, can be installed quickly, and is reliable. They are also relatively cheaper, with deployment cost per line ranging from $1,500 to $3,500 depending on total number of lines.

Advantages of using it for rural areas are

1. Easy and fast set up,
2. High Speeds,
3. Large Distances, and
4. Ability to provide services as and when a customer signs in, unlike the DSL or cable modem, where the entire plant has to be installed first. Hence there is less start-up cost.

Disadvantages involve

1. Requirement for a direct line of sight of the antenna and
2. Bi-directional traffic is not possible in most cases. Even though the capability of this option is improving [22], this upstream data transmission problem may affect negatively certain economic development activities such as telemedicine and teleconferencing [23]. However, now there are both ways satellite services available. For example, the service offered by MSN for anyone with a direct line of sight of the southern sky [24].

Finally, we note that both DSL and cable modem options are relatively dominant over the Wireless/Satellite option with 1.1 million homes in the United States connected by DSL and 2 million homes connected by cable modems [25]. Furthermore, by 2002, it is expected that there will be over 6 million U.S. homes with DSL and 4 million homes with Cable Modems.

3.2.3 Other Advanced Technologies

The other technologies that can be considered for rural areas include the Fiber To The Home (FTTH) and Fiber To The Curb (FTTC). Fiber optic cables are already used by businesses as high-speed links for long distance voice and data traffic. These have tremendous data capacity with rates in excess of one gigabit per second (1000 Mbps).

In an FTTH system, equipment at the head end or Central Office (CO) is interfaced into the public switched telephone network (PSTN). Video services enter the system from the cable television (CATV) head end or from a satellite feed. All of these signals are then combined onto a single fiber using multiplexing techniques and are transmitted to the end user via a passive optical splitter. The splitter is typically placed approximately 30,000 feet from the CO. The split ratio may range from 2 to 32 users and is done without using any active components in the network. The signal is then delivered another 3,000 feet to the home over a single fiber. An ideal FTTH system would have the ability to provide all of the services users are currently paying for, such as circuit-switched telephony, high-speed data, and broadcast video services. At the home, the optical signal is converted into an electrical signal using an optical electrical converter (OEC). The OEC then splits the signal into the services required by the end user.

PON (Passive Optical Networks) is one way of using FTTH and is an all-fiber access system, intended for residential applications for Internet and other services access. As it is all fiber, PON has many advantages. All-fiber yields a robust outside plant that has low maintenance costs associated with it. All-fiber point-to-point architecture allows for secure transmissions and broadband service applications. The PON architecture represents the target wireline architecture because of its versatility and evolution-proof capabilities.

FTTC, on the other hand, means sharing a fiber optic line to a certain hub, located a little away from a group of users. From there onwards, twisted copper wires are used for the transmission of data. Some public utilities are also exploring or beginning to offer broadband access via fiber inside their existing conduits. Additionally, some companies are investigating the feasibility of transmitting data over power lines, which are already ubiquitous. While enormous data rates are possible through power lines, significant technical barriers remain (e.g., eliminating noise from the signals, since power lines have lots of noise associated with them.)

Fiber optic cables as the means of providing broadband access to areas where there is no other form of technology may not be very expensive when compared to copper wire or cable TV. This is due to the declining cost of fiber optics. The initial cost of installing fiber may be higher than the other technologies, but in the long run fiber may turn out to be the better alternative. This is because of the low maintenance compared to copper, which requires replacement every seven years [26] and the fact that telephone and cable services can also be provided on fiber networks.

However, if other systems such as copper networks or cable TV networks already exist in the area, one way would be to upgrade the existing networks to provide broadband access. The advantage is that the existing infrastructure can be utilized for providing broadband access. But the disadvantage would be to end up with a less advanced technology in the long run.

An alternative to this approach would be to install a new fiber network. This may prove to be expensive compared to upgrading the existing plant to provide broadband access. Also the existing plant will have to be discarded. In this case, there should be a considerable amount of demand in the area that will guarantee some payback on the investment. Several telephone companies are exploring ways to provide FTTH at a reasonable cost [27].

Finally, we emphasize that the cost of deploying broadband technology consists of several components, and varies among the deployment options [28]. Considering the magnitude of the cost as well as the long-term consequences of selecting an option for broadband deployment, an objective & quantitative as opposed to subjective & qualitative economic evaluation of the options may be required. In section 5, we illustrate a case of economic evaluation in detail.

4. KEY DEBATES

In recent years, the Internet has emerged as a powerful tool for economic development in rural communities. Moreover, the speed and the capacity of Internet services have been enhanced by the introduction of broadband technology. However, broadband deployment strategies and practices vary substantially from one rural community to the next. This is due to the technology options available. Each of these technology options has certain characteristics, which make them suitable for use under different scenarios. These scenarios are determined by demographic and economic factors. These factors make the decision more complex and hence require scientific analysis in selecting the right technology.

This section is organized as follows:

- Debate on two key issues in broadband deployment.
- Issues of open access policy in broadband deployment and the technological constraints involved.
- Additional issues of general interest in broadband deployment.

The key issues for broadband deployment are (1) whether to build over an existing infrastructure or deploy a new infrastructure, and (2) how best to match businesses with technological options. The current practice in other rural communities can aid the practitioners in the decision-making process regarding these issues. The relevant studies [29], thus far, often compare the last mile technologies available in a qualitative way. However, few quantitative models have been developed for analyzing the technology options.

It has been suggested that the competitive market force will provide relevant technology options so that the customers and businesses will have their choice of technology without worrying about the technology options to be constructed. This may work well for urban areas with high population density because they are the preferred target areas for the investor-owned private broadband service providers.

This, however, is not the case for rural areas with low population density, which may make them unprofitable for the service providers. Also we have seen that the network infrastructures are considerably different for the various technologies available. Hence, selecting the optimal infrastructure that would guarantee appropriate services becomes important for economic development practitioners.

Empirically, however, we are not certain if objective and quantitative decisions regarding the choice of technology and its infrastructure are being made based on information available to economic development practitioners (see e.g., the case of Lusk, Wyoming in Section 6, Current Practice). We do observe various technology options in practice. For example:

- Mid-River Telephone Cooperative is installing a fiber optic cable network in Montana [30].

- Valley Telephone Cooperative in Texas offers a Rate Adaptive Digital Subscriber Line (RADSL) [31].

- Rural Alaska utilizes wireless as the medium for broadband deployment [32].

These examples clearly show how the options for broadband deployment.

A related question is what to do with the existing infrastructure. For example, a radical deployment strategy would be to completely replace an old copper network with a new fiber optic cable network. A conservative deployment strategy would be to partially replace an old copper network with a new fiber optic cable network (i.e., utilize the existing infrastructure to the extent possible). Once again, there have been few attempts that we are aware of to quantify the deployment strategy selection process (radical vs. conservative), and to derive conditions under which one strategy is favorable over the other.

A related question remains as how to match various technological options with the businesses that may utilize them technological options. That is, will the technology option provide the businesses with the appropriate level of capacity and speed? For example the DSL technology has its distance limitation that is aggravated by the presence of loading coils on the telephone network (loading coils on the telephone network are used to provide voice services to far off customers). We analyze the various factors that are critical in making decision among various choices of technology using Analytic Hierarchical Process (AHP) as a quantitative tool (we refer readers to Section 5).

There are also policy issues affecting broadband deployment. For example the issue of open access policy. Open access is the ability of the customer to choose his/her own Internet Service Provider (ISP) for information on the Internet. The cable modem companies providing broadband services usually provide their own affiliated ISP's to the consumers and who can obtain information only from them. The cable operators may also charge substantial open access fees or the cable operator may not allow open access. This may restrict the choice of customers [33] and the operator may become a monopoly.

There are also technological constraints on the cable operator's ability to provide open access. However, there are instances where these technological constraints have been overcome [34]. For example**,** ADC, a company manufacturing broadband equipment, has already made available a product called the "cuda 12000", which allows cable operators to accommodate multiple ISPs on their network.

Open access may not be necessary to ensure competition in the broadband market [4]. The reason is that cable operators are in no position to dominate the broadband market. Also the cable industry faces significant technical, operational, and financial challenges. Finally, an open access requirement may not lead to the significant competitive development currently occurring in the cable modem industry. The reason is that open access may slow down investment by the cable companies in broadband services because they feel threatened.

Other issues of general interest are how early the two-way broadband services will be available to all, and who will provide these services [34]. According to the report, only two technologies, Cable Modem and DSL are being deployed at a high rate. But most of these deployments are taking place in the urban areas. The primary reason for slower deployment of these technologies in rural areas is economic. At the same time, other technologies such as wireless technology and other advanced wireline technology are also planned for rural areas.

Chances of wireline technologies such as cable modem provided to rural areas with widely dispersed population by investor-owned private companies are small. At the same time these technologies can be quite feasible for small towns. Hence, the question of who brings broadband services to rural areas needs to be addressed in consideration of the existing infrastructure, the current/potential service providers in that area, etc.

The emphasis on fiber optics as a solution is characterized by declining average costs over the whole range of demand, which may result in natural monopolies. This is a more important debate for the rural areas, because they are facing the challenge of attaining some form of broadband access, and their priority might not be setting up competition immediately.

Finally, we note that the current telecommunication industry is characterized by rapid technological changes, unpredictable market/product development, and regulatory uncertainties. This implies that there are new and significant risk elements in broadband technology deployment [36]. In spite of these financial risks due to technological, market-based, and regulatory uncertainties, there have been few attempts to model and analyze the decision-making process under these risks. Hence, given the complexity of the issues and the magnitude of time and capital investment [14], an objective and quantitative analyses will complement and improve the decision-making processes.

5. DECISION SUPPORT MODELS FOR INVESTMENT IN BROADBAND DEPLOYMENT AND MULTI-CRITERIA DECISION-MAKING

Selection of the optimal technology to attract businesses to rural areas is a critical issue that may benefit from a quantitative decision-making model. Little work has been done in applying decision models to the area of technology selection in telecommunication industries. This issue of technology selection is complex due to the large number of criteria (e.g., speed, security, cost) that make a certain technology more suitable and the others less suitable.

Case studies from rural communities can aid in decision making to an extent. But their utility is limited since each rural community differs in its demography. In addition, rural areas often have scarce resources to experiment and little margin for error. These are some of the primary reasons for a quantitative, objective model for decision support purposes.

In this section, we first discuss the fundamental factors and methods that can be used for objective and quantitative evaluation of broadband deployment options. We next consider the cost factors in determining the optimal technological options (e.g. DSL, cable modem, fiber optics) based on net present value (NPV). We then broaden our criteria for optimal technology selection by considering additional factors such as speed and security. For this type of multi criteria decision-making, we will employ an analytic hierarchical process (AHP) [37]. Finally, we illustrate the key features of the evaluation with detailed numerical examples here and in the Appendix.

In general, the optimal option for broadband technology deployment (e.g., DSL) will depend on:

- Current state of the telecommunication infrastructure and service.
- Current usage of the infrastructure and service.
- Current and future demand for improving and expanding the infrastructure and service.
- Current and future demographic information (e.g., the number of skilled workers).
- Economic costs and benefits for improving and expanding the infrastructure and service.

5.1 Model Factors for Net Present Value

For any objective and quantitative evaluation of broadband deployment options, a cost-benefit analysis may be required. The basic methods used for this analysis include: the payback period method, the net present value (NPV) method, and the internal rate of return method. Among these, the most widely used method is the NPV method. This method calculates the present value of each investment option, and selects the option with the highest net present value for investment [38].

To employ the NPV method, the following cost factors must be taken into consideration:

1. Development Cost, which includes the cost of procuring the equipment and implementing the appropriate information infrastructure.

2. Transition Cost, which is the cost of moving from the old to the new infrastructure.

3. Operation-Maintenance Cost, which covers the expenses that are related to the operation of the infrastructure and the cost of its maintenance.

4. Depreciation Cost, which considers not only the normal wear and tear, but also potentially rapid technological obsolescence of the infrastructure.

Calculating these cost factors, in turn, involves a large amount of technical and economic information. For example, the Tree/Branch type Hybrid Fiber Coax (HFC) cost per line with two-way capability is estimated at $1,125 with 65% penetration rate. The major components of this cost estimate are the costs of deploying the feeder cable, two-way upgrade, drop cable, and addressable converter. The ADSL cost per line is estimated to start from $500-600, increasing with the speed of service. Finally, the Fiber To The Home (FTTH) cost per line ranges from $1,500 to $3,000 while the Fiber To The Curb (FTTC) cost per line ranges from $1,000 to $1,500 [39].

These cost factors and components, in conjunction with expected benefits from the broadband technology deployment, constitute the net cash flows of the investment. The net cash flows will be used to calculate the net present value (NPV) of the investment as follows [38]:

NPV = $\sum_{t=0}^{n} F_t (1+i)^{-t}$

Where

t = an index of periods (0, …, n), typically one period per year.

F_t = the net cash flow in period t.

i = interest rate per period over the planning horizon (0, …, n).

To illustrate the decision process over the broadband deployment options, we present the following case study.

5.1.1 Case Study: Upgrading Cable TV System to Hybrid Fiber Coax (HFC) System

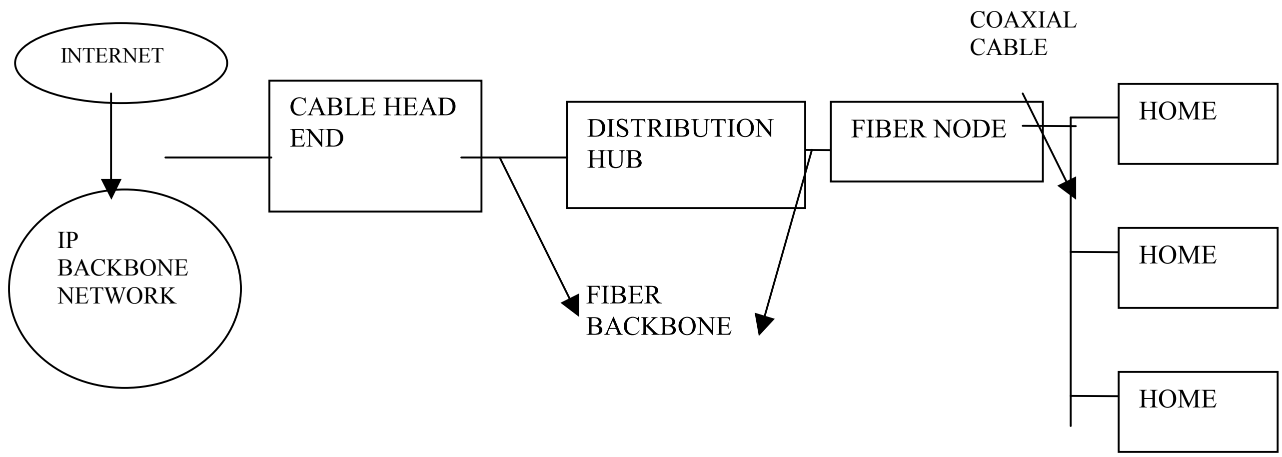
The conventional cable TV system was designed for one-way transmission (provider to customer). Therefore, in order to deploy broadband technology, the cable TV system must be modified to allow two-way transmission. This modification is achieved most widely by upgrading the cable TV system to the HFC system [40].

A typical way to upgrade a cable TV system to a HFC system involves three steps [41] and [42]:

1. Implementing a fiber overlay process where fiber optic cable is deployed to 1,000-home nodes.
2. Replacing broadband amplifiers for the existing co-axial copper wires with high-bandwidth broadband amplifiers.
3. Activating a reverse transmission mechanism, enabling two-way transmission.

The corresponding HFC system architecture is as follows [43], [44], [45], and [46]:

Figure 1: HFC System Architecture



This case study is an example of the cable modem option for broadband technology deployment. It is also an example of a conservative deployment strategy, in which an old copper network is partially replaced by a new fiber optic cable network.

5.1.2 Cost Components in Upgrading Cable TV System to HFC System

In this section, we present the major cost components for upgrading a cable TV system to an HFC system. The values shown here are derived from various sources [43] and [46].

Fixed Development Cost

HFC Upgrade Cost:	\$700–800/Customer
Two-way Upgrade Cost:	\$2,000/mile
Server Cost:	\$60,000

Operation-Maintenance Cost

Personnel Cost:	\$90,000/year (\$60,000+\$30,000) (system administrator and a technical support respectively)

Variable Cost

Each New User:	\$529 (\$500+\$29 for a R/F Modem and Installation Charge)

Expansion Cost

System Administrator/1,500 Subscribers
Technical Support Person/750 Subscribers
T1 Line/1,000 Subscribers
Frequency Translator/500 Subscribers
Server/3,000 Subscribers

The values of the cost components are not exact numbers, but are reasonably approximated numbers for simplicity. Given these data, in the first part of the Appendix we show in details how the net present values can be calculated.

In this section, as well as in the first part of the Appendix, we show how an economic development practitioner can utilize the NPV method to quantify the net benefit of each broadband deployment technology. We believe that this is an important first step to establish a quantitative and objective decision-making process.

After this first step, there are several important extensions that should be considered in the near future. For example, the uncertainties and the corresponding financial risks should be incorporated in the decision making process. A sensitivity analysis can be applied to the expected cash flows, number of customers, and number of periods in the planning horizon. The sensitivity analysis will be valuable in finding out how a change in a particular factor affects the remaining factors. For example, the change in the availability of skilled workers on operating costs. In this way, the practitioner will be aware of the financial consequences (intentional or unintentional) of deviating from the expected values.

Furthermore, in this section, we focus on only the easy-to-quantify factors, such as the costs for software and hardware. However, from the economic development practitioner's perspective, it may be worthwhile to incorporate the overall welfare improvement of the community into the decision making process. Of course, quantifying overall welfare improvement objectively would be a major challenge.

In the next section, we propose a simple and well-known method to compare technologies when easy-to-quantify and hard-to-quantify factors co exist. The criteria that are considered are the ones that affect the performance of the technology selected. This includes the characteristics of the option as well as of the area to be served and the nature of the demand that exists.

5.2 Analytic Hierarchical Process for Multi Criteria Decision-making

Multi criteria decision-making implies that more that one criterion is used to arrive at the decision. Analytic Hierarchical Process (AHP) provides a way of doing this in a very logical and simple manner. The utility of AHP is that it can include hard-to-quantify criteria as well. In decisions such as the selection of technologies for rural areas, use of such hard-to-quantify criteria may be common. AHP is a simple and effective way of quantitatively comparing the options, but requires intuition and experience in the area of the application. A straightforward example of this model as applied in the electric power industry is shown in [37].

The various criteria that can be considered in the selection of the appropriate technology for broadband deployment may include (but are not limited to) the following.

- **Cost**

The cost of investing in a certain technology includes the capital cost of investment, the cost of discarding the existing network, if any, the cost of service as explained in the previous section.

- **Speed**

The speed of the network can be compared directly and can also include the ability of the architecture to provide reliable speeds at different load levels.

- **Security**

How prone is the network to security breaches such as hacking is the data being transmitted over the network? This may depend on the network architecture e.g. Cable Modem architecture has a shared network making it more prone to hacking and interception.

- **Telephone Services**

The ability of the technology to integrate with telephone switches to provide voice communications. Cable and DSL both can provide integrated voice services along with broadband data access.

- **Current Infrastructure**

Existing infrastructure can affect in the investment decision. For example if a cable modem infrastructure is already available, then it will be preferred to new investment on a DSL network.

- **Uncertainty**

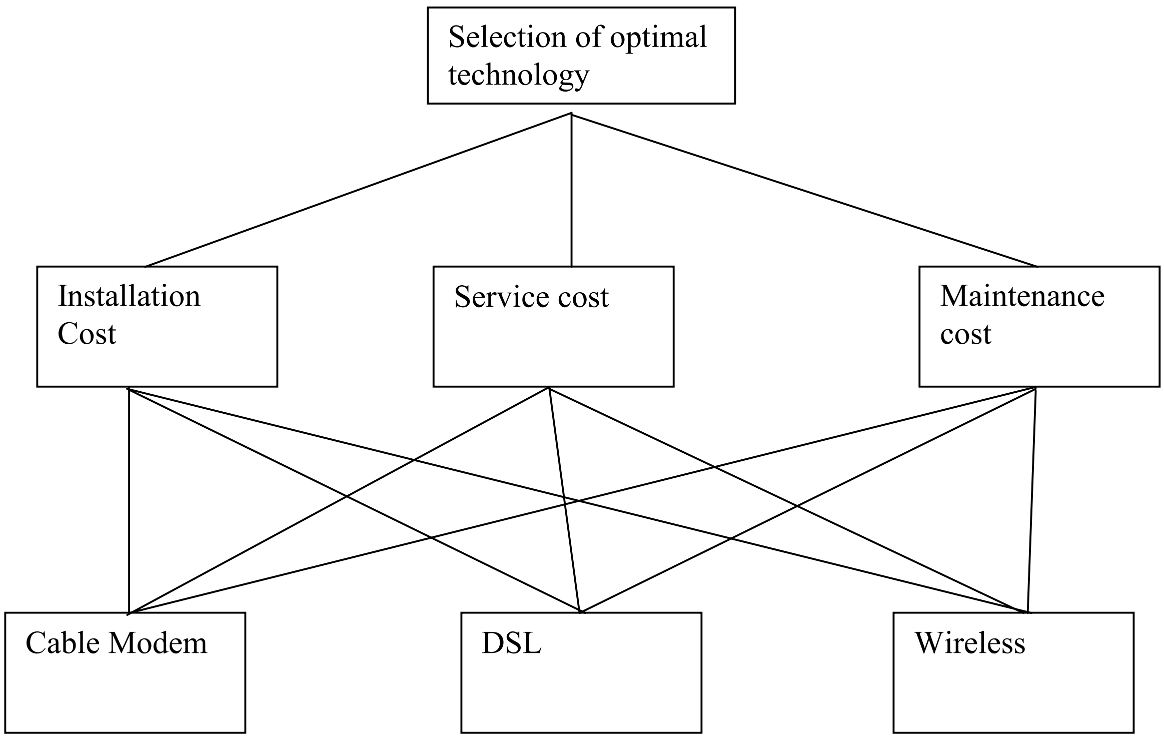
The future worth of the technology depends upon trends in the industry. It should take into consideration advances in the industry that could drastically change usage of a particular technology, which could affect the investment value.

- **Usage**

The amount of usage that the targeted businesses will have with the broadband technology needs to be quantified. A few studies have been done in this regard, which list the usage by the operations in information technology [10]. A few other studies have identified the factors that lead to a rural industry adopting information technology [4].

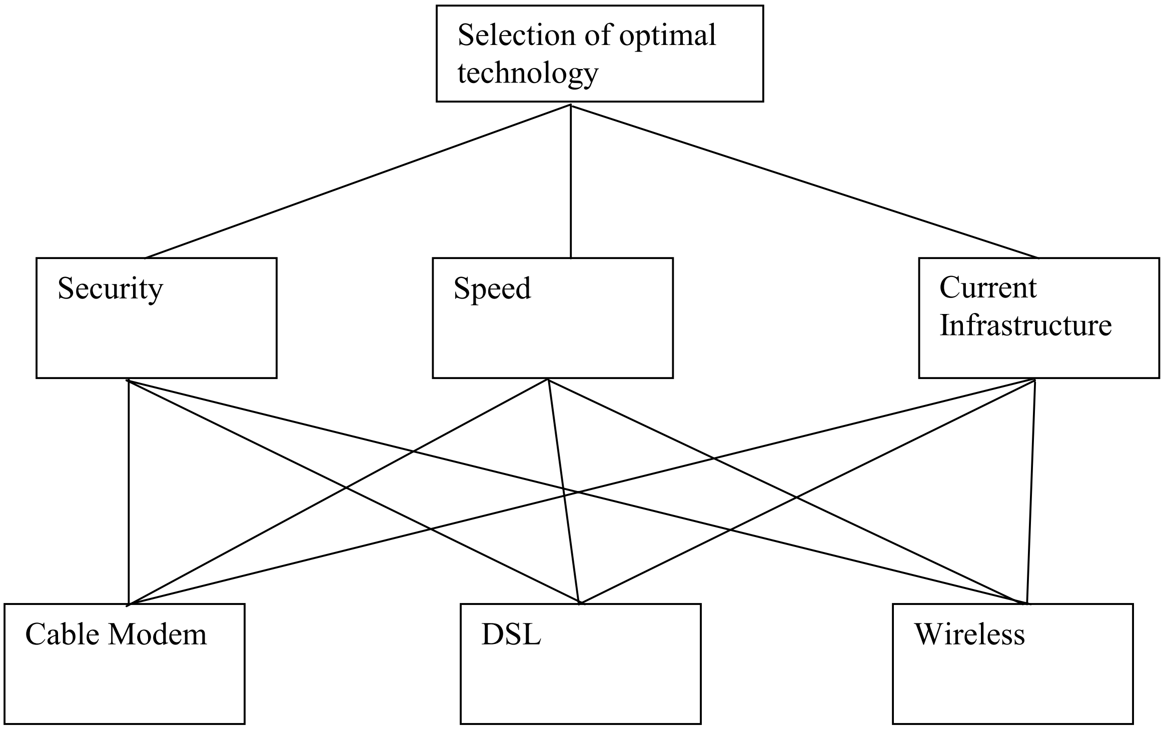
The following figure 2 shows the hierarchy of the criteria considered. For a more detailed explanation of the AHP hierarchy, we refer to Saul Gass [47].

Figure 2: The Hierarchy for the Cost Criterion



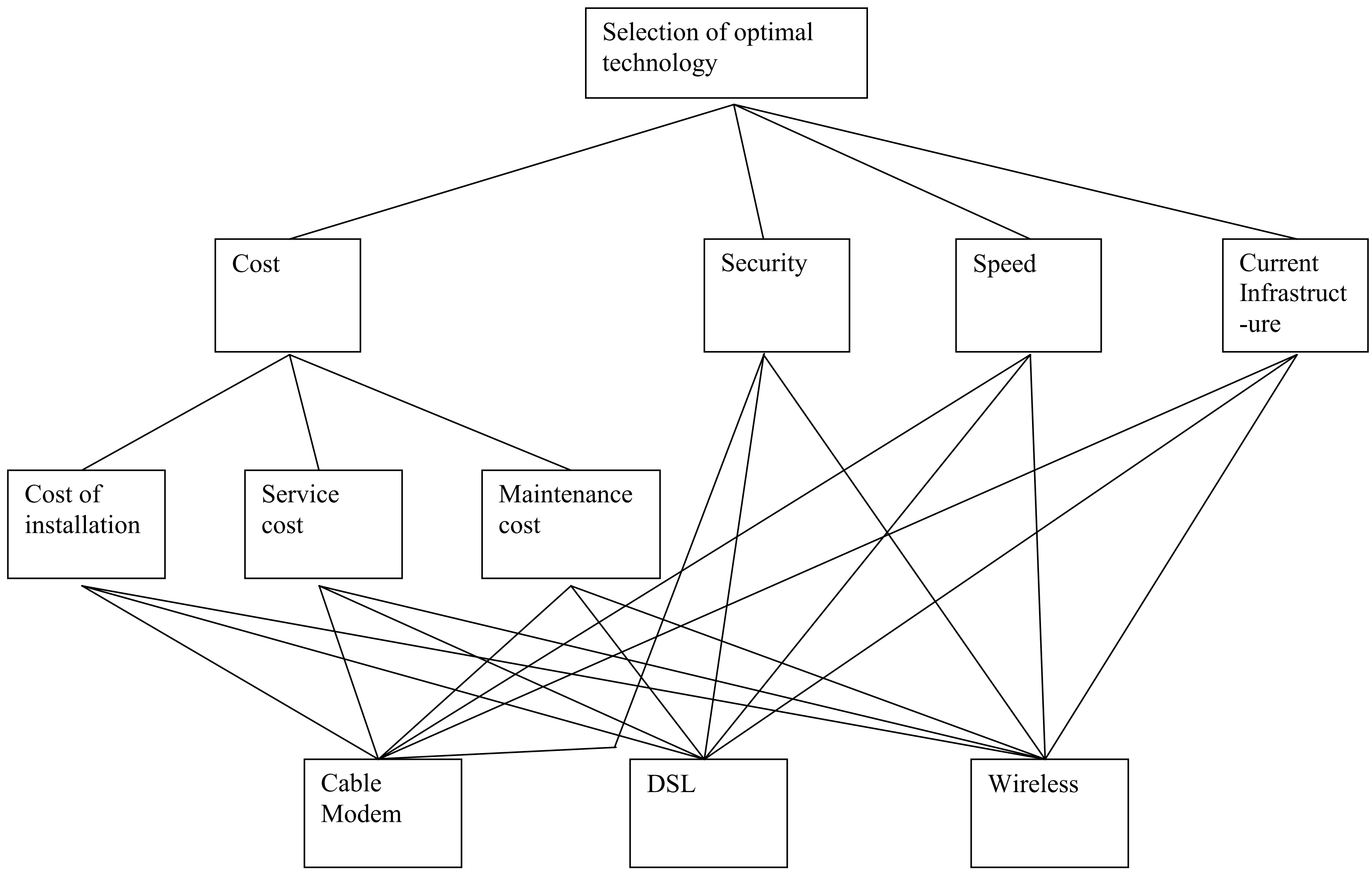
In the figure, each alternative represents a technology under consideration for deployment. Each will have a certain level of installation, service, and maintenance cost associated with it. Other criteria, e.g. security, speed, etc. will have a similar hierarchy, as shown below.

Figure 3: The Hierarchy for Security, Speed, and Current Infrastructure Criteria.



Finally the hierarchies will be joined to form an overall decision model as shown in Figure 4. Each of the criteria has to be quantified and the calculation from the AHP provides ranks to each option being considered. The option with the highest rank is the one that will perform the best. There is a detailed quantification of AHP with an example in the second part of the Appendix (p.38). The example in the Appendix shows how one can compare three basic access technologies (i.e., DSL, Cable Modem, and Wireless) based on the factors mentioned earlier.

Figure 4: The Combined Decision Model.



6. CURRENT PRACTICES

The most commonly deployed broadband technologies today are the DSL and cable modem [48]. However, rural areas have not benefited much from these advancements in technology, since the deployment is mostly limited to urban areas with high population density and demand. A detailed comparison of DSL and cable modem for the next few years has been presented in the report *"DSL vs. Cable Modems: The Future of High-Speed Internet Access 2000-2005"* [49]. According to the report, cable modem has an advantage over DSL because the cable modem infrastructure is often already installed by cable operators, whereas DSL infrastructure is not yet installed by the telephone operators. Hence, cable operators can provide broadband access to their customers with very little additional investment in the network infrastructure. On the other hand, the report states that in the future DSL will catch up with cable modem because of the relative advantage (i.e. more stable speed) and recent construction of the infrastructure [50] and [51]. These observations, however, may not be directly applicable to rural areas because neither cable modem nor DSL are often available in rural areas.

As an alternative, wireless technologies are currently under investigation for providing broadband services in rural areas. These are mostly the Multichannel Multipoint Distribution System (MMDS) or the Local – Multipoint Distribution System (LMDS). MMDS is quite promising because it can cover vast areas (up to a 35 mile radius), provided there is a line of sight. LMDS operates at a much higher frequency and hence can serve a relatively smaller area (up to a 5 mile radius). One example is the use of LMDS in Goldwaithe, Texas. [52].

FTTH, on the other hand, can be considered as advancement to the existing DSL or cable modem infrastructure. Currently, there is some of fiber in the cable modem and DSL architecture. FTTH extends this to the home directly. Hence, both the telephone companies providing DSL and the cable companies can provide FTTH. The cost of FTTH can be similar to DSL or cable modem when a complete rebuild is being done or a new plant is being build [52]. This implies that FTTH can be a viable option for rural infrastructure that has none of the advanced technologies for providing broadband access. When FTTH is considered as an extension of the existing fiber network to the home, it is an enhancement of the technologies. However, if it is complete reconstruction it can be considered as a technological alternative. An example of FTTH can be seen in Huxley, Iowa, where a fiber line delivers video, telephone, Internet, and other data services to the customer at a very rapid speed. Another example is deployment of FTTH in Lusk, Wyoming, [36] and [53].

An example of FTTH deployment is East Otter Tail Telephone Company [27], which needed to replace the 30-year-old, deteriorating copper cable in its rural network serving a low population density area. Instead of installing new copper cable, the company is deploying a FTTH network. The copper cable installation cost is estimated at $3,000/subscriber whereas the FTTH installation cost is estimated to be more than $5,000/subscriber. Given the significant cost difference, the company is attempting to implement cost saving measures in its FTTH network.

Similarly, a Kansas-based rural telephone company [54] is replacing its traditional copper-based infrastructure with a passive optical network based on FTTH technology. Other examples include Mid-River Telephone Cooperative [30] installing fiber optic cables in Montana, Valley Telephone Cooperative [37] offering the rate adaptive digital subscriber line (RADSL) service in Texas, and Rye Telephone Company [31] implementing an FTTH network in Colorado.

For economic development practitioners, it is essential to take all important cost factors and risk factors into consideration in the decision making process for broadband deployment. The lack of an objective and quantitative analysis can result in total or partial failure to attain the objectives of the project. For example, the fiber optic deployment in Lusk, Wyoming, did not result in optimum benefits because the expected demand was not realized after the investment. The town of Lusk has a population of about 1,500. The town had determined that fiber optic cables would be economically justified, and had built a substantial network of fiber optic and coaxial cables [54] and [55]. However, due to errors in forecasted demand, Lusk ended up with an incomplete fiber optic network and a huge deployment cost [14] and [56]. This case can serve as a warning in broadband deployment when substantial errors are possible in forecasting the demand for the fiber optic cables. The demand factors can be estimated from the businesses that are being targeted as possible future customers in the area. In order to make such a forecast we need to know the type of businesses that can operate in a rural environment as discussed in section 2. Once this is known, the amount of IT-related operations in these organizations and the amount and nature of demand can be projected. We strongly believe that the technology investment should substantially depend on this demand.

In identifying potential industries some rural areas have concentrated on the back-office firms, which are mobile and can locate anywhere. [11] gives the following examples:

- In LaGrange, Georgia, the city leaders decided that the best strategy was to concentrate on back-office operations. In order to stay competitive in attracting hi-tech companies, LaGrange officials identified three important components that were necessary. They are digital switches, fiber optics, and a long-distance point of presence.
- A similar example of such practice is Sioux Falls, Iowa, where Citicorp has operated its credit card processing since 1981.
- Tri-State Insurance operates its back office in LaVerne, Minnesota.
- Northstar Mutual Insurance Company operates in Cottonwood, Minnesota.

Only a few examples can be found where the investment in technology was made with good foresight and reasoning. One example where the technology and the business were considered together during the planning period can be seen in Durango, Colorado. Durango has expanded its economy by attracting telecommuting companies that rely heavily on access to information superhighway (Internet). The local electric company provided advanced telecommunication services to the area. LaPlata, an electric company in Durango provided the advanced telecommunication services to the area by providing the infrastructure. The major problem under such circumstances is for the utility company to decide on which technology to select [57]. This example not only shows a good practice where the planning involved the targeted company but also shows a case where the provider for broadband access can be different from traditional telecommunication companies.

Another example is Maple Lake, Minnesota, where a cable company coupled with an electric company to provide broadband access. The cable company used the electric company's right-of-way and in turn provided cheap access to the electric company. These examples open up a whole new dimension for providing rural areas with broadband services by involving electric utilities and water co-ops in the business of broadband access. Since big telecommunication companies are not likely to build services on rural communities, it may be that rural electric and telephone co-ops can help rural areas in gaining access to the telecommunication [57]. Also Midland, Ontario (a community of 25,000 residents) deployed a high-speed wireless data network utilizing the existing structure such as water towers and buildings within the community (see http://www.wi-lan.com/success/story_midland.html). This practice has also been noted in Brooksville where a telephone company is paying thousands of dollars per year for the right to put antennae on the county's three elevated water towers [64].

Bellsouth, Georgia is installing a high-grade copper system to meet ADSL requirements so that all of Georgia has access to broadband services. This is being carried out under the Business Expansion and Support Act (BEST) [58], and provides a way of marketing Georgia as an ideal place for companies to relocate, since they do not have to rely on metro areas for access to broadband services. This brings about economic development in all of Georgia, as a whole and not just to the most populated areas. Apart from attracting new industries these investments will also make broadband access available for schools in the state. Teleworking is one of the areas that are being looked into for bringing new industries into the area [59]. Teleworking is the ability to work remotely from the office. This gives the rural population a chance to obtain hi-tech jobs that require broadband services.

Wireless deployment in rural Alaska is as an example where upgrading the existing infrastructure has enhanced economic development. Even though Alaska is the largest state in terms of area, the total population is only about 600,000. Furthermore, there are only four communities in the state with a population exceeding 10,000. Many of the rural Alaska communities have traditionally utilized satellites. Currently, this satellite technology is complemented by fiber optic cable network that increases the speed and capacity of communication [66]. This has resulted in increased use of the Internet for economic development in rural areas e.g. telemedicine, education and training and also facilitated Internet-based government and business services.

The above examples point to the fact that rural areas present a unique scenario for providing broadband access [60]. Each rural area is unique, and must have its own optimal solution for providing broadband access. Hence, best practices are documented so that rural areas can learn from the experiences of other rural areas.

Finally, the solutions could include aggregating demand in the area in order to attract more service providers. This can be done through creation of a Rural Area Network (RAN), which are configured around the geographic boundaries and needs of an entire community [63]. This practice has potential benefits such as providing economies of scale and scope by pooling diverse users. These kinds of networks can take advantage of new technologies such as wireless technologies or satellite based technologies. When making a need assessment for a rural community it is advantageous to include all sources of demand to build broad-based support for improved telecommunications. This is especially true for small towns where resources are scarce and strategic planning process need to draw on as broad a segment of the community as possible and to demonstrate a consumer demand for broadband Internet service [14].

7. POLICY IMPLICATIONS

Thus far, we have examined the technical options for broadband technology deployment, deployment in practice in rural communities, and a detailed decision model to evaluate technical options of this economic investment. It is well known that the cost of deployment per subscriber is relatively high in areas with low population density [28] and [61]. This is a major disadvantage for rural communities who want to benefit from high speed/large capacity Internet services for businesses and governments. Considering the large investment and the long-term economic consequences of broadband deployment, for an economic development practitioner, the margin of error in his/her broadband technology decisions and policies may be quite small. For such economic development practitioners, specific policy implications on broadband technology deployment are as follows:

The practitioner should

1. Understand the characteristics of each technical option,
2. Understand the economic aspect of each technical option,
3. Appreciate the technological uncertainties of each technical option (e.g., the remaining life of an option to technological obsolescence),
4. Appreciate the economic uncertainties of each technical option (e.g., migration of businesses from one rural community to the next may have no significance under the wireless/satellite option), and
5. Understand and appreciate quantitative decision-making processes so in order to objectively establish decisions and policies on broadband technology deployment.

A previous paper claims that rural communities with low population will find wireless technologies to be most suitable for their telecommunications requirement [20]. However, in general, not all communities will find the same investment strategy to be appropriate [5]. For example, wireline technology such as Cable Modem and DSL can be more cost effective (relative to wireless technologies) by exploiting the existing infrastructure. Similarly, depending on the specific characteristics of a rural community, the economic development practitioner may have to decide on Internet use priorities (e.g., youth job training vs. senior health care) or Internet service providers (e.g., community governments vs. private companies)

Based on our study there are two central questions for economic development practitioners regarding investment in broadband deployment:

- How can economic development practitioner facilitate appropriate coordination and cooperation among potential partners (e.g. electricity cooperatives, water cooperative districts etc.,) in broadband technology deployment, resulting in the most appropriate infrastructure for the particular community?

- What strategies will work best to encourage the private sector to develop and deploy broadband services to communities with low population density? In order to encourage private-sector participation, what coordination and cooperation strategies will work best between the private and public sectors?

In addressing these questions, economic development practitioners should take account of the following: While implementing the technologies and using the decision process to select technologies, one should clearly understand the requirement based on economic and demographic characteristics. Hence, the practitioner should, to the extent possible, clearly identify, quantify, and understand the factors affecting critical decisions on the broadband deployment and decision-making processes.

There are other policy issues that are important for economic development practitioners and they should be considered in decision-making. One example is the policy of the Federal Communications Commission (FCC) regarding Open Access. Open Access allows customers to choose the Internet Service Providers (ISP) over the infrastructure of cable operators. This may ultimately lead to greater competition between the ISP's.

However, according to Kopel [28], open access may not necessarily bring the advantages into broadband deployment. Specifically, allowing open access may actually decrease the rate at which broadband deployment is taking place now. For example, if the cable operators sense that the open access policy may decrease their returns, they may stop investing in wide spread broadband deployment. Kopel also states that the decrease in investment will not be limited to cable companies but will extend to telephone companies. Moreover, to allow other ISP's to access the cable infrastructure will lead to congestion in the cable network, bringing down the speed of the cable network. This may actually lead to slower deployment of broadband technology [28].

On the other hand, if open access is not implemented, there will be no ISP other than the cable operator's own ISP. This may force the community to subscribe to the ISP that is affiliated to the cable operator, limiting their choices. Promoters of open access claim that Internet should be fully open to customer choices in order to encourage maximum access, innovation, freedom, and diversity, [65].

Finally, as we pointed out before, the decisions and policies for broadband technology deployment require substantial capital and time, and will result in significant impact (positive or negative) on the welfare of rural communities. In spite of such importance, we have found few quantitative and objective models in the existing literature that could be used for decision-support purposes. We believe that such models should be available to economic development practitioners to help them improve the welfare of rural communities.

8. CONCLUSIONS

In this project, we comprehensively searched, collected, and classified information available in published books, journals, and trade magazines, as well as on Internet sites, regarding economic development via the Internet in rural communities. The critical issues examined are the characteristics of rural communities and technological options. We also investigated current practices as well as key debates. Finally, based on the best information available we proposed several decision support models and discussed the policy implications concerning rural economic development via the Internet.

Specifically, in section 2, we introduced an overview of economic development via the Internet in rural communities and various types of businesses that may be appropriate. Next, in section 3, we investigated the technological options available in the deployment of broadband technology such as DSL, cable modem, and wireless. This is followed by the key debates in section 4 on economic development via the Internet such as how best to match businesses with technological options. We then provided a couple of decision support models in section 5 based on the NPV method and the AHP approach, with comprehensive numerical examples shown in the Appendix. Next, we examined a variety of current practices in section 6 involving DSL, cable modem, and Wireless. In section 7, discuss the policy implications where we provide a set of information requirements for economic development practitioners and policy makers. We also discuss the advantages and disadvantages of Open Access issues.

This report serves as a basis for further studies in the area of rural broadband deployment. The basic models and observations made here can be extended in various ways. Each rural area is potential area for development. Many issues such as the optimal selection of the appropriate technology for deployment and open access policies remain unresolved. Furthermore, the various technologies mentioned here need to be studied further as to where they are heading in the near future.

The rapid pace of technological improvement requires that practitioners must keep track of the changes in the technologies. Also, in order to make informed decisions, practitioners must be familiar with the impact of such changes on the decision process.

Finally, the case studies and examples mentioned in this report provide insights on how decisions are currently made and what their outcomes are. Such documentation, we hope, will help practitioners in the decision process by showing them different perspectives and different outcomes. We hope that these studies will help practitioners in their search for effective and efficient ways of bringing economic development into rural areas via broadband technology.

APPENDIX

Net Present Values for the Case Study: Upgrading Cable TV System to Hybrid Fiber Coax (HFC) System

Based on the values of various cost components provided in section 5.1.2 we proceed to show the way of calculating the Net Present Value (NPV).

The various steps involved in the NPV calculation are

- Calculating the cash outflow
- Calculating the cash inflow
- Computing the net cash flow for each year using the cash inflow and cash outflow details
- Finally, arriving at the NPV for the project.

We make the following technical, economic, and demographic assumptions for the calculation:

1. Broadband deployment of HFC (i.e., the cable modem option) has a 5-year project horizon.
2. Population size is 20,000, and the population density is 2 people per square mile.
3. The target penetration rate for the population is 60% or 12,000 subscribers.

Based on these assumptions, the expected miles to be covered will be 6,000 miles.
Under these assumptions, a reasonable cash outflow is summarized in Table 1 as follows:

Table 1: Cash Outflow

YEAR	# OF CUSTOMERS TARGETED	MILES TARGETED	HFC & TWO-WAY UPGRADING @$750/MILE	SERVER + HARDWARE + SOFTWARE @$60,000/ SET	PERSONNEL: SYSTEM ADMINISTRATOR + TECHNICAL SUPPORT	INSTALLATION COST @ $500/ CUSTOMER	TOTAL COST
1	3,000	1,500	$1,125,000	$60,000	$90,000	$150,000	$1,425,000
2	3,000	1,500	$1,125,000	$60,000	$90,000 x 2	$150,000	$1,515,000
3	3,000	1,500	$1,125,000	$60,000	$90,000 x 3	$150,000	$1,605,000
4	3,000	1,500	$1,125,000		$90,000 x 3	$150,000	$1,545,000
5					$90,000 x 3		$1,395,000

For Table 1, we assume that one set of server, hardware and software, one system administrator, and one technical support person are added for every 4,000 subscribers. Also, assume that the annual installation will take one year to complete, i.e., in year 1, there are no subscribers while in year 2, and there are 3,000 subscribers. Finally, for simplicity, we assume that all cash flow occurs at the end of the year.

Thus far, we have examined cash outflow. Let us now examine a reasonable cash inflow as follows: Revenue from this investment consists of a one-time installation charge of $150/subscriber and an annual fee of $480/subscriber. Then, given the number of customers targeted in Table 1, we have the cash inflow summarized in Table 2.

Table 2: Cash Inflow

YEAR	# OF NEW CUSTOMERS TARGETED ANNUALLY	TOTAL CUSTOMERS AT THE END OF THE YEAR	REVENUE		TOTAL REVENUE
			INSTALLATION CHARGE @$150/ CUSTOMER	ANNUAL FEE @$480/ CUSTOMER	
1	0	0	$0	$0	$0
2	3,000	3,000	$450,000	$1,440,000	$1,890,000
3	3,000	6,000	$450,000	$2,880,000	$3,330,000
4	3,000	9,000	$450,000	$4,320,000	$4,770,000
5	3,000	12,000	$450,000	$5,760,000	$6,210,000

Given Tables 1 and 2, the net present value (NPV) of this investment can be calculated as follows [38].

Let Ft be the net cash flow in year t. Then,

F1 = 0 – 1,425,000 = -1,425,000

F2 = 1,890,000 – 1,515,000 = 375,000

F3 = 3,330,000 – 1,605,000 = 1,725,000

F4 = 4,770,000 – 1,545,000 = 3,225,000

F5 = 6,210,000 – 1,395,000 = 4,815,000

If we let i, the interest rate per year, be 6%, then the discounted NPV of the investment is:

$$\text{NPV} = F_1(1+i)^{-1} + F_2(1+i)^{-2} + F_3(1+i)^{-3} + F_4(1+i)^{-4} + F_5(1+i)^{-5}$$

=$6,590,302

Hence, the discounted NPV for upgrading the cable TV system to the HFC system is about $6.6 million.

Other alternative broadband technologies for deployment such as Fiber To The Home (FTTH) and Asymmetric Digital Subscriber Line (ADSL) can be evaluated in a similar way. Once the NPVs of all the technologies under consideration are computed, then the technology with the highest NPV will be chosen for broadband deployment.

Quantification for Analytic Hierarchical Process (AHP) Model

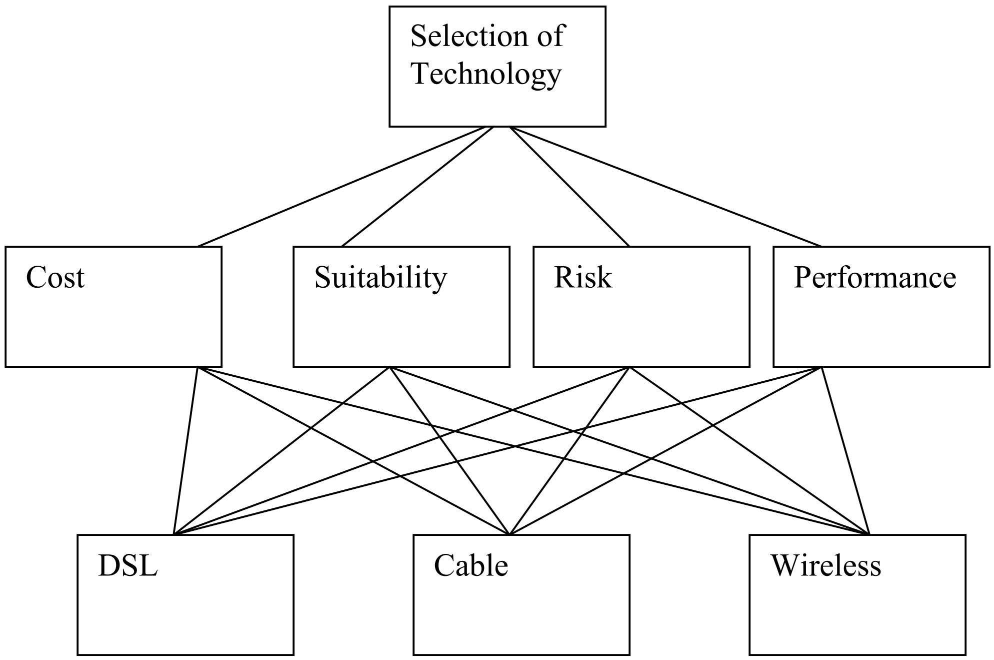
Once the criteria have been identified, they have to be quantified so that they can be compared with respect to each other. For quantifying the criteria, a 1 to 9 system of weights is used with, 9 being the best and 1 being the worst. This is illustrated in the table below; see Saul Gass [47] for more details.

Table 3: The Pair-wise Comparison Scale

INTENSITY OF IMPORTANCE	DEFINITION	EXPLANATION
1	Equal importance of both elements	Two elements contribute equally to the property
3	Moderate importance of one over the other	Experience and judgment slightly favor one element over the other
5	Strong importance of one element over the other	Experience and judgment strongly favors one element over the other
7	Very strong importance of one element over the other	An element is strongly favored and its dominance is demonstrated in practice
9	Extreme importance of one element over the other	The evidence favoring one element over the other is of the highest possible order of affirmation

Let us take an example where we compare three basic access technologies i.e., DSL, Cable and Wireless. This is a hypothetical situation where the practitioner compares the three technologies as investment alternatives in the area under consideration. This comparison is considered with some specific company/industry in mind, which the practitioner plans to attract to his/her community. That is, the practitioner has identified the company/industry as a potential candidate that can relocate and will provide substantial economic benefit to the area. Let us assume that the practitioner identifies the four most important criteria for selection of technology as cost, suitability, risk and performance. Hence the hierarchy of the AHP model will appear as follows:

Figure 5: Model for the Example



To quantify cost we can adopt the NPV method as explained earlier and will have many sub-criteria such as the cost of installation, cost of service, cost of upgrading, and cost of maintenance. These sub-criteria will be weighted for each technology depending upon the locality's being served. This will require an in-depth knowledge of the area's geography, infrastructure, and existing technology and their maintenance requirements. Next, each criterion will be compares based on a pair-wise comparison as in the following Table 4. This table gives us an insight as to how important each criterion is in achieving the objective.

Table 4: Comparison of Criterion

DECISION TO SELECT A TECHNOLOGY	COST	SUITABILITY	RISK	PERFORMANCE	Pi
Cost	1	3	7	8	0.586
Suitability	1/3	1	5	5	0.277
Risk	1/7	1/5	1	3	0.088
Performance	1/8	1/5	1/3	1	0.049

Calculation steps for Pi's:

1) Take the product of the rows. Let us call this value Xi where i is the number of rows or columns.
2) Take the nth root of Xi's, where n is the number of rows or columns for the matrix. For the above matrix n = 4.
3) Add all the Xi's and let this be Y.
4) Now Pi = Xi/Y

In justifying for the above values of comparison it can be argued that cost is easily the highest priority, since rural areas do not have much capital to spend on the infrastructure. Cost might eliminate technologies such as FTTH, which is not being considered here. Suitability is the next highest criterion because one must match businesses with the right kind of technology. This analysis can be carried out by studying the various operations of the company being targeted and finding out how much dependence there is on information technology (IT) and up to what level. Risk can be a measure of the expected change in technology. A technology that has high potential for change in standards or other features resulting in obsolescence can be considered as a high-risk alternative. Performance will include other features associated with the technology, such as speed, which is not covered in the other criteria. The justification for giving performance the lowest priority is that all the alternatives can provide broadband access as defined by the FCC.

Next the alternatives will be compared with respect to each criterion. The following three matrices serve this purpose and the calculations are done similar to above.

Table 5: Pair-wise Comparison for Cost

COST	DSL	CABLE	WIRELESS	Pi
DSL	1	3	5	0.65
Cable	1/3	1	2	0.23
Wireless	1/5	1/2	1	0.12

The cost of DSL is the least because of the existence of good-grade copper wire already installed in the rural area under consideration. Cable may require an upgrade to HFC architecture to provide two-way broadband. Wireless may require investment in towers and antennas, which can be very expensive.

Table 6: Pair-wise Comparison for Suitability

SUITABILITY	DSL	CABLE	WIRELESS	Pi
DSL	1	1/5	1/2	0.106
Cable	5	1	7	0.744
Wireless	2	1/7	1	0.150

Table 6 shows, cable to be the most suitable. This is supported by the fact that there are areas that cannot be reached by DSL, and wireless does not provide sufficient two-way transmission.

Table 7: Pair-wise Comparison for Risk

RISK	DSL	CABLE	WIRELESS	Pi
DSL	1	2	3	0.540
Cable	1/2	1	2	0.297
Wireless	1/3	1/2	1	0.163

Table 7 shows, DSL is the safest because it has been in use for a long time and has been relatively stable. The new upgrades to DSL are easily configurable. On the other hand, cable modem needs standardization and wireless is an area that is still being researched for widespread deployment.

Table 8: Pair-wise Comparison for Performance

PERFORMANCE	DSL	CABLE	WIRELESS	Pi
DSL	1	3	5	0.627
Cable	1/3	1	4	0.280
Wireless	1/5	1/4	1	0.093

In Table 8, the basis for comparison could include speed at all times, security, and ease of maintenance.

It should be noted that the above quantifications are assumed values. The success of the model will depend on the practitioner's perception of the situation and experience. A more detailed mathematical model can be used to quantify criteria such as cost, which can be broken down into various components.

We summarize the above calculations in Table 9, where the composite hierarchical priorities are calculated.

Table 9: Final Priorities

CRITERIA	COST	SUITABILITY	RISK	PERFORMANCE	COMPOSITE HIERARCHICAL PRIORITIES
Level 2 priorities	0.586	0.277	0.088	0.049	Pi
DSL	0.65	0.106	0.540	0.627	0.489
Cable	0.23	0.744	0.297	0.280	0.381
Wireless	0.12	0.150	0.163	0.093	0.131

The composite hierarchical priorities are calculated by taking the sum of the products of the level 2 priorities and the level 3 priorities for each alternative.
i.e.,
composite hierarchical priority for DSL is,
(0.586 * 0.65) + (0.277 * 0.106) + (0.088 * 0.540) + (0.049 * 0.627) = 0.489

In Table. 9, DSL has the highest priority, and should be the selected technology.

As we demonstrated by an example, AHP provides a quantitative and scientific way to compare options. A strength of AHP is its independence on the number of criteria that are being used. This is the reason that this model was chosen as it provides the flexibility of considering different criteria for different rural areas. i.e., each area being considered may have a different kind of situation and the criteria on which the decision has to be made will vary. AHP allows the introduction of weights to the criteria, which provides more flexibility for the decision maker. Moreover it combines experience and perception with a scientific model, which is very important in selection processes of this nature where intuition and criteria that are non-quantifiable can be encountered.

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