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Overview of New Technology Deployment Model: Broadband with Associated Depreciation and Overheads

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Telecommunications Industries Analysis Project:
Overview of New Technology Deployment Model: Broadband with Associated Depreciation and Overheads

Carol Weinhaus, Linda Garbanati, Gordon Calaway, et *al*.
March 15, 1995.

This software was developed by Carol Weinhaus and members of the Telecommunications Industries Analysis Work Group. The Telecommunications Industries Analysis Project is associated with the Public Utilities Research Center and the University of Florida College of Business Administration.

For information on this research, contact Carol Weinhaus at:
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Project Information

List of Participants in the Telecommunications Industries Analysis Project, 1995

State Regulators	NARUC representatives from: Illinois Commerce Commission Iowa Utilities Board Massachusetts Department of Public Utilities New York Public Service Commission Washington Utilities and Transportation Commission
Regional Holding Companies	Ameritech Bell Atlantic BellSouth NYNEX Pacific Telesis SBC Communications Inc. U S WEST
Independents	Anchorage Telephone Utility GTE Sprint Local Telecom Division
Interexchange Carrier	AT&T Sprint
Foreign Domestic	InfoCom Research, Inc. NTT America
Local, National, and International Services	BT France Telecom North America
Materials Manufacturers	Corning
Telecommunications Equipment Manufacturers	Northern Telecom

Sponsors:

Corporation for Public Broadcasting

Assisting with *public* data:

Bellcore
Federal Communications Commission
National Exchange Carrier Association

Background on the Telecommunications Industries Analysis Project

The goal of the Telecommunications Industries Analysis Project (TIAP) is to provide information to support the development of alternative communications policies to meet the needs of stakeholders in an environment that includes competitive and non-competitive markets, federal and state regulatory jurisdictions, and a proliferation of new services made possible by technological advances. The purpose of the project is to produce research and analysis which will assist policy makers in making informed decisions.

The project is a neutral forum of communications industry stakeholders exploring multiple viewpoints on selected issues. This forum incorporates the following elements:

- **Broad representation:** The current forum includes local exchange carriers, interexchange carriers, materials and equipment manufacturers, and regulators. The project actively seeks expansion of this forum to include other communications industry representatives such as competitive access providers, cable television companies, computer companies, electric power utilities, and publishers.

- **Multiple viewpoints:** Participants are required to have an active role in the research and analysis, to represent their own interests, to understand and to assist in developing others' perspectives, and to work toward the common goal of representing multiple views.

- **Analysis and results of alternative policies:** Research tools, including a jointly produced data base and computer software models, and data analysis developed by this forum create a common language for examining issues. The common language allows the participants to focus on underlying issues. Appropriate computer software tools are developed, and existing tools are modified.

- **All data, analysis methods, and results are public:** Data used by this project must be publicly available on a nationwide basis. Research products become public domain information.

- **Neutral setting:** The project resides in a neutral setting, free of partiality, thereby ensuring objective and independent research.

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List of Acronyms

ATM	Asynchronous Transfer Mode
ARMIS	Automated Reporting Management Information System
Broadcast TV	Broadcast Television
Cable TV	Cable Television
CPE	Customer Premises Equipment
FCC	Federal Communications Commission
IN	Intelligent Network
ISDN	Integrated Services Digital Network
LEC	Local Exchange Carrier
Mbps	Megabits per Second
MSA	Metropolitan Statistical Area
NECA	National Exchange Carrier Association
OMB	Office of Management and Budget
PON	Passive Optical Network
PSN	Public Switched Network
SONET	Synchronous Optical Network
TIAP	Telecommunications Industries Analysis Project
USOA	Uniform System of Accounts
V&H	Vertical and Horizontal Coordinates

Overview of New Technology Deployment Model, March 15, 1995

Objective of the Model
The objective of the *New Technology Deployment Model* is to identify and quantify the associated issues - regulatory, technical, financial, and market demand - that will assist policy makers in their decisions concerning competition and new technology deployment. The modeling process also identifies key elements associated with broadband deployment and analyzes the result of changing these key elements.

This tool enables regulators, telecommunications companies, and others to experiment with various deployment options and to analyze the results.

Public Debate over Advanced Communications
There's an ongoing public debate about the deployment of advanced communications technologies referred to in the press as the information superhighway. Included in these debates are several issues:

- Is a broadband superhighway too expensive to deploy today?
- Who should be allowed to deploy it?
- What should be the role of government?
- What technologies should be deployed and when?

One viewpoint in the debate is that deployment of narrowband Integrated Services Digital Network (ISDN) would meet a vast majority of market needs within a shorter time frame, and at a fraction of the cost of full broadband deployment. On the other end of the spectrum, there is the view that broadband deployment must be ubiquitous to meet market needs.

The essential differences between these two views are the speed, cost, and the extent of the deployment of broadband. The New Technology Deployment Model uses a definition for the nationwide broadband network that lies somewhere between these two views. The model allows for variations in implementation scenarios and schedules.

The Debate Should Change
Some of these questions over technology deployment are already being answered in the marketplace. Therefore, rather than focus on who the providers are and what technologies they should provide, the debate needs to shift to: How will the multiple network providers be allowed to operate so that customers can get what they want at a reasonable price? Some customers want the new technologies, some don't.

Research Results
Research results (Figures 1 through 5) based on this model indicate that broadband deployment is reasonable if done in markets where there is demand or if there are changes in policies that define industry structure (such as allowing companies to offer both basic telephone and cable television, or cable TV, services).

Ideally, analyzing broadband deployment on a nationwide basis within the overall public switched network (PSN) would require examination of all networks. This model analyzes

a specific deployment issue for only one segment of the multi-vendor environment - the cost of local exchange carrier (LEC) deployment of a broadband network. Only the LECs file public data in a standardized nationwide format; no comparable data are available for other providers - such as competitive access providers, cable TV companies, or personal communications networks. Results vary when different technologies, other deployment schedules, and alternative network providers are analyzed.

Basic Design of Model [1]

By design, the model requires the user to set a scenario for deployment of the nationwide broadband infrastructure and for a penetration rate for various market segments. The user specifies a number of assumptions: the starting date for broadband deployment, the annual (variable) percentage of network conversion, the annual access line growth rate, the annual percentage (variable) rate for investments for network equipment caused by the penetration of broadband services on the infrastructure, and various financial assumptions.

- ***Broadband Technology Deployment Component:***
  The heart of the model, this component looks at broadband deployment for only the LECs on a nationwide basis or by market segment. User input allows variations in deployment rate, market selection (business, residential, national, metropolitan, rural, and custom), and level of deployment (number of wire centers converted by size, and number of access lines converted).

  This portion of the model yields estimates for investment costs by selected market size for broadband and wideband transport equipment, switches, fiber cable, and associated ancillary devices. This includes the ability to calculate the capital investments for each year required to deploy a national broadband infrastructure schedule. The model also assumes network statistics on wire center counts, average network access line counts, and subscriber densities and distributions from wire centers.

- ***Associated Depreciation and Overhead Component:***
  Regulatory financial requirements have a profound effect on a LEC's ability to purchase technology for infrastructure evolution. This component calculates the depreciation expenses resulting from the profile of capital investments developed in the technology deployment component. The depreciation component allows variation in depreciation rates for all affected investment accounts. It also allows variation in the amount of overhead costs associated with broadband deployment.

[1] For detailed information on the model, consult the *New Technology Deployment Model: Broadband with Associated Depreciation and Overheads, User Guide, 1992 Nationwide Data Set,* March 15, 1995

Examples of Deployment Patterns
Sample runs from the model indicate monthly revenue requirements per line per customer for various market segments: nationwide (**Figure 1**), urban and rural (**Figure 2**), and business and residential for nationwide, urban, and rural markets (**Figures 3, 4, and 5**).

The model applies various financial components to broadband investment costs to produce these revenue requirements. (Revenue requirements are the sum of Return on Investment, Depreciation, Maintenance, Overheads, and other expenses.)

The graphs showing the revenue requirements per line per month throughout this manual use the following naming conventions:

- ***Benchmarks: 1992 Telephone Revenues per Telephone Line***
  In order to give some indication of the magnitude of output from the model and to provide a yardstick for current customer bills, the figures in this section contain benchmarks. Benchmarks are revenue requirements for Tier 1 local exchange carriers (per customer per month, including basic service, state toll, and access). The benchmarks for the three market segments are as follows: $49 for nationwide, $49 for urban, and $50 for rural.

  Note that these benchmarks use only local exchange carrier revenues. They do not examine the impact of competition or the effect of additional revenues from other potential sources (whether current services such as cable TV or new services which have yet to be developed); therefore, the benchmarks represent a marker rather than an exact threshold.

- ***Cost for Modern Telephone Network Carrying Only Traditional Telephone Services***
  Indicated by the lines labeled "Broadband Infrastructure," these make the following assumptions about access lines: 100% broadband capable and 0% broadband equipped. Broadband capable means that:

  - All copper feeder and distribution facilities (loop) have been replaced with fiber.
  - An asynchronous transfer mode (ATM) switching adjunct has been added to the central office (wire center).
  - Current services are deployed on this fiber infrastructure.

Therefore, all customers subscribing to narrow-band services will continue to receive these services. Most of the capable costs are for the conversion of the copper lines.

- ***Cost for Telephone Network Carrying Broadband Services***
  Indicated by the lines labeled "Broadband Services," these make the following assumptions about access lines: 100% broadband capable and 100% broadband equipped by the end of 20 years. Each year the total number of lines equipped to provide broadband services increases by 5% of the total capable lines.

"Broadband equipped" is the cost for the telephone network carrying broadband services. A line must be broadband capable in order to be equipped; equipped lines are a percent of only those lines that are already broadband capable.

The difference between the equipped and the capable curves is the additional cost for equipping capable lines to provide broadband services. For a customer to receive broadband services, costs beyond those associated with converting an access line to broadband capability are required. Additional costs for equipping include the costs of channelization of broadband services near or at the customer premises, broadband switching capabilities at the wire center (switch), and transport through the interoffice network for broadband services. These facilities are new and not a replacement of existing facilities.

In the model, the point at which the capable curves cross the 1992 revenue line is sensitive to the percent of access line growth. Overhead assumptions and maintenance reductions affect this point as well.

Figures 1 and 2 indicate the following patterns:

- Existing telephone revenues on average **(Benchmarks)** are adequate to cover the cost (revenue requirement) of building and maintaining modern (fiber optic infrastructure) telecommunications networks in some markets **(Urban, Broadband Infrastructure)**, but only if the networks provide only traditional telecommunications services. In other markets, deployment costs require revenues from additional services **(Rural, Broadband Infrastructure)**.

- The increased cost of upgrading these modern telecommunications networks to carry broadband services **(Urban and Rural, Broadband Services)** will vary for different types of customers. New revenues from other sources, such as new broadband services and non-traditional services (e.g., video dial-tone) will support these additional costs.

In **Figures 3, 4, and 5**, the cost of providing business broadband services along with current services is higher than residential broadband services because the service definitions in the model give business significantly more capabilities and capacity. It should also be noted that business services tend to generate more revenues than residential services. In addition, the cost of deployment of the business broadband infrastructure is lower than that for residences. The difference between the business infrastructure and business broadband services curves is primarily due to the difference in facilities required at the switch (ATM adjunct).

Figures 3 and 4 follow similar patterns: all the curves except for the business broadband service curve hover below the 1992 benchmark revenue line. Also note that for residential deployments, the cost of adding broadband services to a broadband infrastructure is minimal.

Figure 5 shows a different pattern: with the exception of the business infrastructure curve, the other curves are above the 1992 benchmark revenue line. The reason for the low business infrastructure revenue requirements is due to very short business loops associated with the rural switches (small wire centers).

Cumulative Investments
The investment for providing the **Nationwide Broadband Infrastructure, Figure 6**, produces a cumulative nationwide investment of $231 billion over 20 years. This $231 billion is the estimated cost for the entire network including loop, switching, and interoffice transport for both business and residential customers. The investment for providing **Nationwide Broadband Services, Figure 6**, produces a nationwide investment of $416 billion dollars.

Using a 1992 benchmark helps assess the results of the cumulative investment reports. Projecting the 1992 additions to total plant for all local exchange carriers over 20 years produces a cumulative investment of $406 billion. [2] (This assumes that current spending levels continue.) The comparison of this 1992-based benchmark indicates the following:

- Providing the fiber optic infrastructure defined by the model falls well within the current spending levels.

- Equipping everyone in the United States for broadband services, including the cost of the infrastructure, is comparable to current spending levels. **Figure 6** shows nationwide capital investment components for the same run that produced **Figure 1**.

Modeling Assumptions Used for Deployment Examples
All the deployment curves used in this manual as examples also use the following assumptions:

- 2.35% growth rate in access lines per year.
- 0.5% decrease in general overheads per year,
  which produces a 10% decrease in the lump sum over 20 years.
- 1.81% increase in the direct overheads per year,
  but assumes a 10% decrease per access line over 20 years. The increase in the lump sum is due to growth in access lines.
- 11.25% rate of return on investment (default).
- 5.1% average state income tax rate (default).
- 35% federal income tax rate (default).
- Default book and tax lives.
- A modified S-Shape as defined by the default deployment schedule.
- Number of broadband-capable access lined equipped for broadband services increases 5% per year.

[2] See **Section VIII**, for the development of 1992 benchmark for cumulative investment data.

The decision to deploy broadband is determined by a number of individual market characteristics such as access line growth, distance of customers from the central office (affects cost of technology), company costs, and demographics. Normally a local exchange carrier performs a cost-benefit analysis to determine where and when the new technology should be deployed. In some cases, the decision to deploy a particular technology would be made even if it were not immediately economically justifiable; however, it would be expected that a service would be deployed only if there were an established demand and a plan for cost recovery.

Caveats on Broadband Deployment Results
What this model provides is a realistic threshold for LEC costs for deploying broadband technology. The results of the model reflect specific network architecture and particular service offerings.

The resulting conversion investment costs produced by this model are an overstatement for several reasons:

- In the model, the deployment is uniformly spread out over long and short lines, and over high and low density populations (based on user input values). Normal deployment selects specific markets where there is customer demand for initial deployment or when equipment upgrades are needed; therefore, the model overstates the costs to some degree since the model is nationwide and not market driven.

- The revenue requirements per line are averages. Therefore, caution should be exercised in making assumptions about costs for individual lines converted to broadband.

- The model assumes that the existing network is replaced with broadband technology. The model does not calculate any of the retirements of the old network equipment. The analysis in this paper captures all maintenance, overheads, and other costs through several factors.

- The model assumes there is only one broadband service provider in an area.

- The model excludes customer premises equipment such as televisions, television set tops, telephone sets, or personal computers or other equipment that the end user must purchase to attach the equipped access line. The model also excludes costs associated with developing information content, such as video services, cable TV shows, and information data bases.

- The model applies the interstate rate of return to all investments regardless of whether the investments are state or interstate.

Network Functions and Features
The participants of the Telecommunications Industries Analysis Project reached a consensus on desired generic functions and features for a broadband network and a terminology to describe the derivation of broadband services.

A "platform," in very general terms, gives a generic capability. The specific services that a customer receives on this platform can vary. The following list covers some services that can be provided on this generic platform:

- **Entertainment:** Broadcast TV, basic cable TV, pay-per-view, narrow-casting, and video-on-demand.

- **Interactive Video:** Games, multi-media libraries, video-conferencing, formal education, and how-to-videos (start and stop and learn from).

- **Transactional Services:** Yellow pages directory, catalog shopping, grocery shopping, banking.

- **Publishing:** Telecommuting, digital radio, and real-time polling.

In more technical terms, a "platform" is the basic underlying capability upon which the service can be configured by adding hardware/software. In this model, fiber is the platform and there is flexibility to allow services to be personalized to the individual subscriber.

For example, if this concept were applied to the computer, the platform would be the microprocessor itself (e.g., 486) and the associated wiring, cabinet, and power unit. Adjuncts added to provide specific services would be the monitor, keyboard, mouse, and software. In the case of local access, "platform" refers to cable facilities, passive devices, powering equipment and cabling, initial switching and interoffice transport capability, enhancements to operation support systems for normal operations, administration and maintenance, and personnel training.

Recognizing issues - such as varying patters of customer acceptance and the necessity of engineering networks with sufficient capacity to handle current as well as future demand - the participants "sized" the fiber-optic platforms for business and residential customers for the following average service deliveries:

- **Residential platform** provides work at home (data transfer, video conferencing, faxing, etc., all simultaneously) in addition to traditional voice. It also provides entertainment and other one-way video services.

  This platform should support an average of one switched wideband signal (up to 1.544 Mbps) per current residential access line (making work-at-home applications possible) and one broadcast video signal (providing video on demand) per person per

household. In addition, this platform also provides current residential narrowband service.

- **Business platform** provides enough bandwidth to support a burgeoning need for higher than 64 kilobit business services (quality video-conferencing, two-way interactive data services, primary and basic rate ISDN). It also has a dynamic allocation of bandwidth that lets the customer reconfigure the network in real-time to meet tailored business needs.

  This platform should support two switched wideband signals per current business access line, as well as all current business services. Additionally, a business with a mix of wideband and broadband services should be able to reconfigure its own access to the PSN up to the information capacity of services purchased.

A single "broadband" service is defined as one offered at data rates of 45 Mbps or greater. It is worthy of note that the majority of broadband services derived off these platforms arise from residential broadcast video or from multiplexed narrowband and wideband signals to business buildings.

Additional network features include electronic interfaces at customer and network interconnection points; network power sources and power back-up customized to customer density; and integration of narrowband, wideband, and broadband services on the same fiber. The subscriber is met electrically, not optically in this model.

Network Architecture Components
In order to model the transition to a broadband capable network, it was necessary to consider national trends. These trends cover features and functions and network components. For example, current national trends include the following transitions in network technologies:

- Analog to digital.
- Narrowband to broadband (including wideband).
- Asynchronous to synchronous transport.
- Unintelligent to intelligent CPE and networking features.
- Circuit-switched and packet-switched to cell-based.

The major technology components and service features that the broadband model is based on are as follows:

- Fiber platforms for service offerings.
- PONs (passive optical networks) architecture.
- SONET (synchronous optical network) equipment for interoffice networks.
- ATM (asynchronous transfer mode) switched traffic for residential video and large business broadband services.
- Advanced IN (intelligent network) for new service creation environments.

- Digital switches capable of Integrated Services Digital Network (ISDN) services for the near term.
- Integration of operational support systems.

Development Process

The *New Technology Deployment Model* and its companion *1995 User Guide* are part of a continuous line of research on public policies and technology deployment, specifically the deployment of a broadband infrastructure and broadband services.

Rather than follow the path of traditional economic forecasting, namely, "Forecast often, but forget past forecasts," the project provides a trail documenting the research process. The objective is to produce research results that are relevant to ongoing issues while preserving the integrity of the research process. Since May 6, 1993, when the earlier version of the *User Guide* was released, a number of modifications and revisions have been made to the *New Technology Deployment Model*. [3] The impact of these changes is as follows:

- Improved understanding of the issues.
- Generation of new ideas for future research.
- Better understanding of the factors underlying the current research results.
- Insight into how the model might be modified to address additional questions.

Revisions and Added Capabilities

The changes in the model provide the user with greater flexibility and ease of use. The major changes are as follows:

- Market Segmentation: Nationwide, urban, rural, and custom for business, residential, or both.
- Infrastructure Platform: business, residential, or both.
- Default Schedules for Wire Center Conversion: Uniform or modified S-shape.
- Overheads: Direct and general categories, ability to factor in access line growth, and incorporation of separate overhead amounts for existing copper wire facilities.
- Error checking of user input.

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[3] Carol Weinhaus, Dr. Linda Garbanati, *et al., New Technology Deployment Model: Broadband and Depreciation Models, 1989 Nationwide Data Set, User Guide (1993 User Guide),* Telecommunications Industries Analysis Project, Center for Telecommunications Management, College of Business Administration, University of Southern California, May 6, 1993. Results from the initial model also appear in Weinhaus, Carol; Pitts, Teresa; et al., *Beyond Future Shock: Need for a New Response to Technological Change*, November 13, 1993; results from the first revision appear in *Abort, Retry, Fail* and in *The Cost of Mandating Technology*. Weinhaus, Carol; Pitts, Teresa; et al., *Abort, Retry, Fail? The Need for New Communications Policies,* July 11, 1994; revised October 10, 1994; Figure 8, page 11, and pages 19-22; and Weinhaus, Carol; Makeeff, Sandra; *et al., Redefining Universal Service: The Cost of Mandating the Deployment of New Technology in Rural Areas,* July 18, 1994, pages 23-37.

Illustration of Changes in the Model
To illustrate the impact of changes in the model, compare the nationwide cost curves in **Figure 1** with those using the earlier modeling assumptions (**Figure 7**, which represents 1993 assumptions and **Figure 8**, which uses 1994 assumptions) in the current (1995) model. The costs are for all access lines, both those converted for the broadband infrastructure and those not yet replaced with fiber. In these versions using earlier assumptions, the patterns are similar to those of the current model. However, the amounts are slightly higher.

Impact of Modeling Changes
The differences in current curves as compared to the earlier versions of the model are primarily caused by the following factors:

- The total revenue requirement amount is divided by all access lines and not just the broadband capable ones.

- The 1995 results are also lower because of the treatment of overhead loadings (more accurate in treatment of current trends and in division into general and direct categories).

- The flattening of the curves (instead of "ski-slope" in the earlier versions) is due to:

  - The assumption that all growth in new access lines occurs in wire centers already converted to broadband.

  - A lowering of the initial volume for the ATM switch-deployment learning curve in the first four years of deployment.

  - Expenses associated with the capital investments for migration to new technology are incorporated into the total expense picture for the LECs.

Major Changes in 1995 Version of the Model
The following list indicates major changes that affect the output of the model:

- Data sources for the current model are all updated to 1992. Earlier versions of the model use mixes of data from 1989 through 1992.

- The benchmark revenue line in the current charts changes because different overhead factors are used and the source for access line counts is consistent with the source for the embedded investments and expenses. The result is a lowering of the nationwide benchmark from $55 in the earlier papers to $49 in this manual.

- The current model allows for greater accuracy in overhead loadings on a per line basis. In all versions of the model, the user input for access line growth and the treatment of the overhead loadings affects the point at which the monthly revenue

requirement (or cost) per access line curve crosses the 1992 benchmark revenue line.

For example, if the overhead loadings are kept constant and the input for percent of access line growth is increased, then the cost per access will decrease. Earlier versions of the model allowed only a single per line loading factor for overheads. Therefore, as the number of lines increased, the total overhead expense increased. It was not possible to account for decreases known to be associated with technologies and other industry trends. The latest version of the model allows for either increases or decreases on a per line basis in the overhead loadings, and changes in ongoing maintenance for new technology.

- The current model also splits the overhead loadings into direct and general. This allows greater accuracy in assumptions for costs directly associated with technology deployment.

- The current model and the interim version used for *The Cost of Mandating Technology* permit variation of the percentage of capable access lines equipped for broadband services on a yearly basis. In the earliest version of the model, the assumptions allowed only a fixed percentage of converted access lines to be equipped. The result was less flexibility in modeling realistic deployment scenarios. The current model is a more accurate reflection of technology deployment: as costs for a given technology decrease, more of the technology is installed.

- The current model has built-in features that produce reports without having to perform off-line calculations. The result is that the revenue requirements per line curves and the cumulative investment amounts are easily generated. Earlier, all displayed statistics were calculated externally.

- In the revenue requirement (or cost) per line curves the underlying definitions for loops has changed in the current version of the model. Previous versions referred only to those access lines converted to broadband capable. The current version uses all access lines (both copper wire and converted) to develop the per line revenue requirements.

  This version also treats maintenance and other basic loop costs for converted and unconverted lines differently. The result is that the cost per line is an average across all access lines, and more accurately represents what is normally meant by LEC Revenue Requirements.

- Earlier versions of the revenue requirement per line curves are based on a uniform deployment of broadband services each year. Each year, the same percentage of capable access lines are equipped for broadband services. In the current version, this percentage of equipped lines can be varied on a yearly basis. This allows for smaller deployment volumes of new technologies in the initial years, with greater volumes in later years, which reaps the benefits of decreased costs and improvements as the

technology matures. It also provides a more accurate modeling of likely broadband service penetration.

- The current model assumes that all growth of new loops occurs only in those wire centers already converted to broadband. The earlier versions of the model assumed that loop growth was applied uniformly to all wirecenters. Therefore, a relatively smaller proportion of growth loops were converted to broadband capable in these earlier versions. The result is that in the current model, the cost per capable loop in the initial years is lower than in previous versions of the model. The current model more closely resembles probable deployment patterns.

- Regardless of the reduction in technology costs based on volume (deployment learning curves) there is always some cost. In the current model, the threshold for minimum cost was lowered for the ATM switching and for high-speed electronics. The impact of this change occurs in the last few years of deployment and its effect is minimal.

- In the current model, the initial volume for the ATM switch-deployment learning curve is lower in the first few years of deployment, and only affects investments in the first few years of deployment.

Data Sources

1992 V&H Coordinates:
NECA data filed in Tariff Federal Communications Commission No. 4, 63rd Revised Section 3, April 1, 1992.

1992 Access Lines:
Calculated from FCC, *Monitoring Report*, Prepared by the *Staff of the Federal-State Joint Board in CC Docket 80-286*, CC Docket No. 87-339, Table 4.19, June 1, 1993. Data filed in accordance with the FCC's Establishment of a *Program to Monitor the Impact of Joint Board Decisions*, DA 89-503, Released May 12, 1989.

1992 Percent Switches that are Digital:
Data Specifications and reporting requirements for the ARMIS Infrastructure Report (FCC Report 43-07) are described in the *Automated Reporting Requirements for Certain Class A and Tier 1 Telephone Companies (Part 31, 43, 67, and 69 of the FCC's Rules)*, CC Docket 87-313, DA 91-619, Released May 17, 1991. Uses 1992 data set.

MSA and non-MSA:
The U.S. Office of Management and Budget (OMB) sets the standard definitions of metropolitan areas.

Development of 1992 Benchmark for Cumulative Investment Data:
Based on Additions to Total Plant, *ARMIS* Report 43-02, Line 260, 1992 data, for total Tier 1 local exchange carriers. This amount was multiplied by a factor representing the ratio of total network access lines to total Tier 1 access lines to account for the remaining

non-Tier 1 companies (FCC Monitoring Report, Table 4.19). The calculation is: $18.6 billion * 1.092 = $20.3 billion.

ARMIS 43-02 and ARMIS 43-03
Data specifications and reporting requirements for the ARMIS USOA Report (FCC Report 43-02) and ARMIS Joint Costs Report (FCC Report 43-03) are described in the *Automated Reporting Requirements for Certain Class A and Tier 1 Telephone Companies (Part 31, 43, 67, and 69 of the FCC's Rules), Errata*, CC Docket 86-182, DA 89-136, Released February 8, 1989.

FCC, *Monitoring Report, Prepared by the Staff of the Federal-State Joint Board in CC Docket 80-286*, CC Docket No. 87-339, Table 4.19, June 1, 1993. Data filed in accordance with the FCC's *Establishment of a Program to Monitor the Impact of Joint Board Decisions*, DA 89-503, Released May 12, 1989.

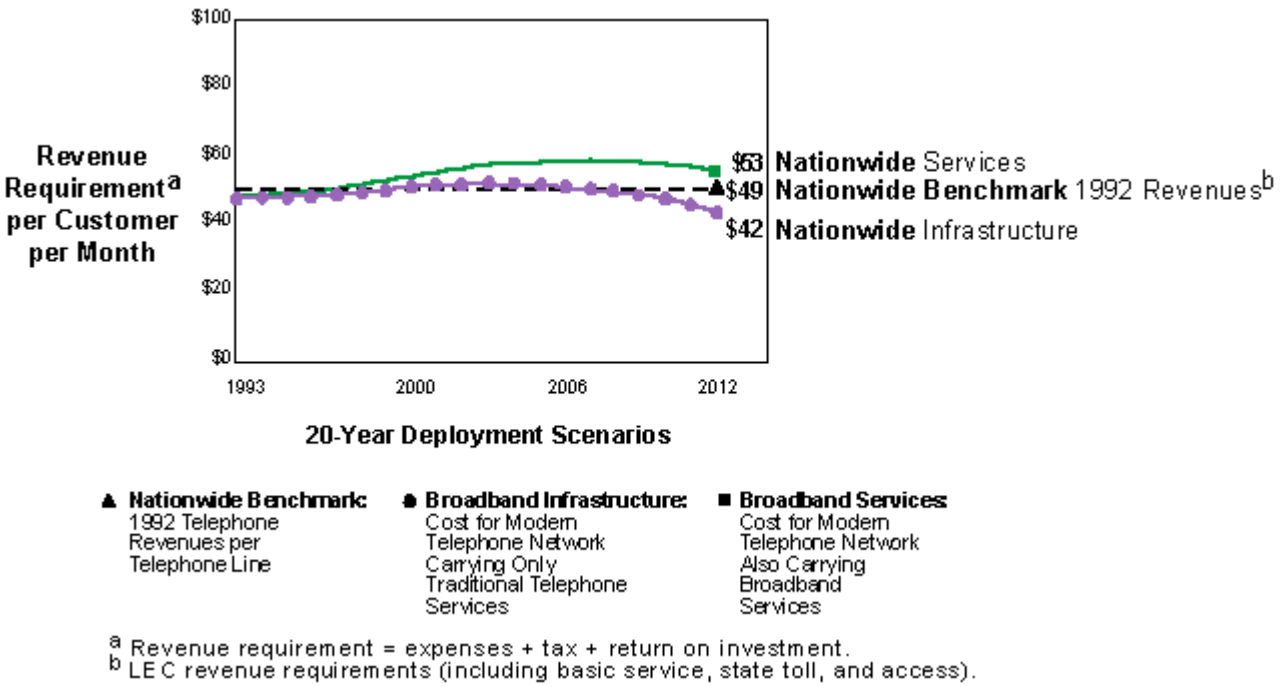
Development of 1992 Revenue Requirement Financial Factors and Benchmark Revenues:
The model applies various financial components to broadband investment costs to produce revenue requirements. The financial factors and variables used in the model are based on 1992 financial data filed in the FCC *ARMIS* Reports 43-03 and 43-04. Data on smaller companies are from the FCC *Monitoring Report* and other sources. The accounts used as the basis for reporting financial data are from the Uniform System of Accounts (USOA).

The basic factors and revenue data from *ARMIS* Reports develop the 1992 benchmark revenues. Revenue Requirements are the sum of Investment Expense, Maintenance Expense, Overheads, and other expenses. The revenue requirement covers both unconverted copper loops and the new fiber replacement.

ARMIS 43-04
Data specifications and reporting requirements for the ARMIS Access Report (FCC Report 43-04) are described in the *Automated Reporting Requirements for Certain Class A and Tier 1 Telephone Companies (Part 31, 43, 67, and 69 of the FCC's Rules), Errata*, CC Docket 86-182, DA 90-30, Released January 16, 1990.

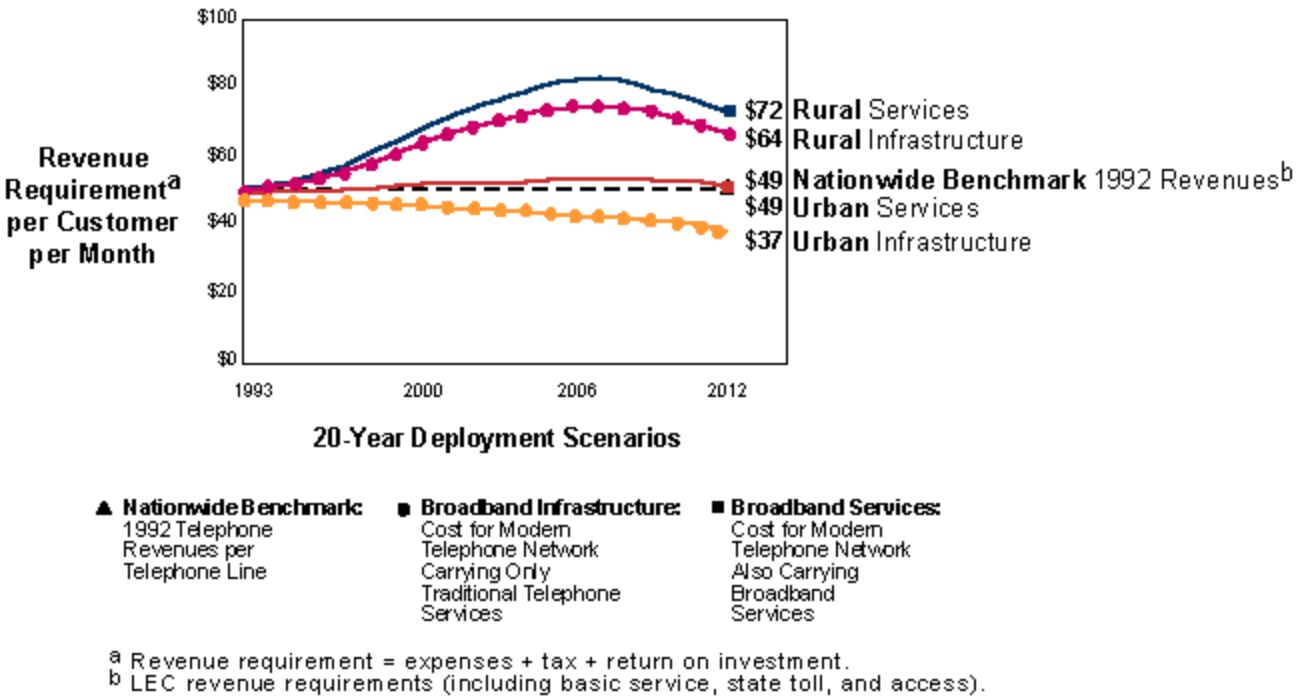
Average Access Line Statistics:
The average loop length statistics for comparison with CUSTOM market segment input are from J.T. Hawley and R.A. McDonald, "The Technological Evolution of the Loop Plant. III," Telephony, Vol. 207, No. 22, November 19, 1984, pages 56-64.

Figure 1
Cost of Local Telephone Company Deployment of Broadband: Nationwide, All Access Lines



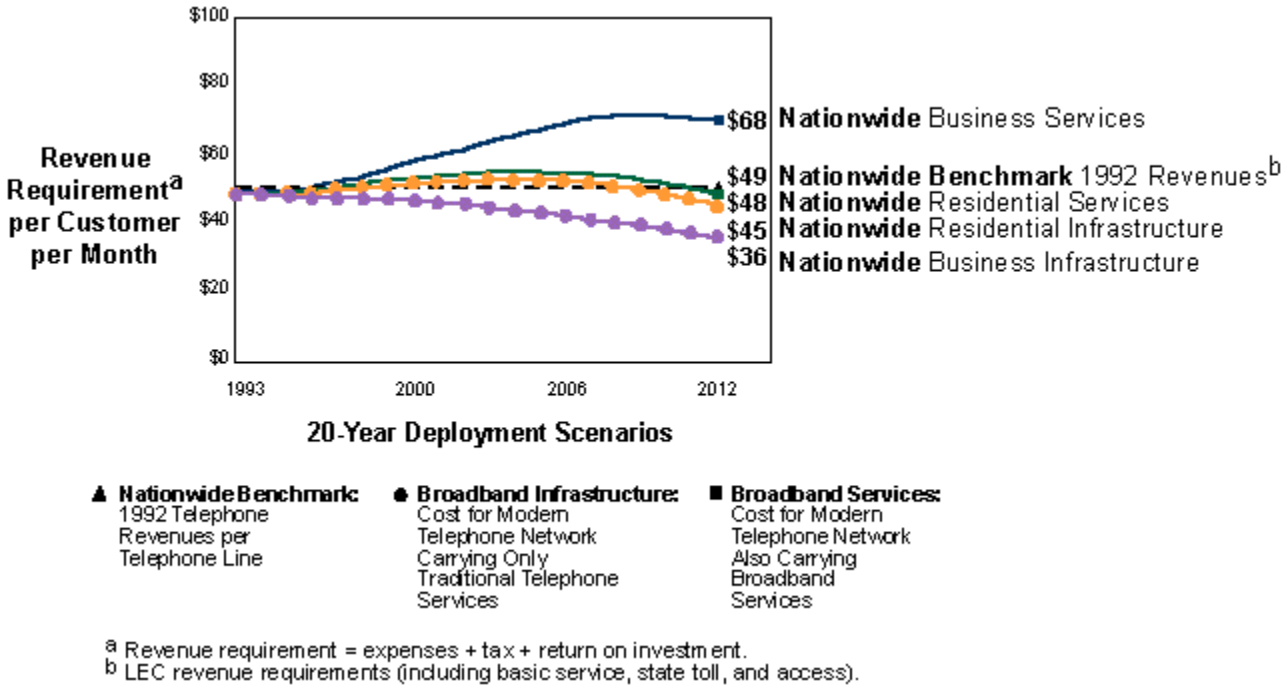
Note: Assume a 2.35% annual growth in nationwide access lines, For the Broadband Services curve, each year 5% of broadband-capable access lines also become equipped for Broadband Services. The Nationwide Benchmark of $48.98 is a calculated revenue requirement for Tier 1 local exchange carriers (LECs) divided by the number of access lines for Tier 1 LECs. Costs are for all access lines (broadband-capable plus non-converted).

Figure 2
Cost of Local Telephone Company Deployment of Broadband: Urban and Rural, All Access Lines



Note: Assumes a 2.35% annual growth in nationwide access lines. For the Broadband Services curve, each year 5% of broadband-capable access lines also become equipped for Broadband Services. The Nationwide Benchmark of $49.98 is a calculated revenue requirement for Tier 1 local exchange carriers (LECs) divided by the number of access lines for Tier 1 LECs. Costs are for all access lines (broadband-capable plus non-converted).

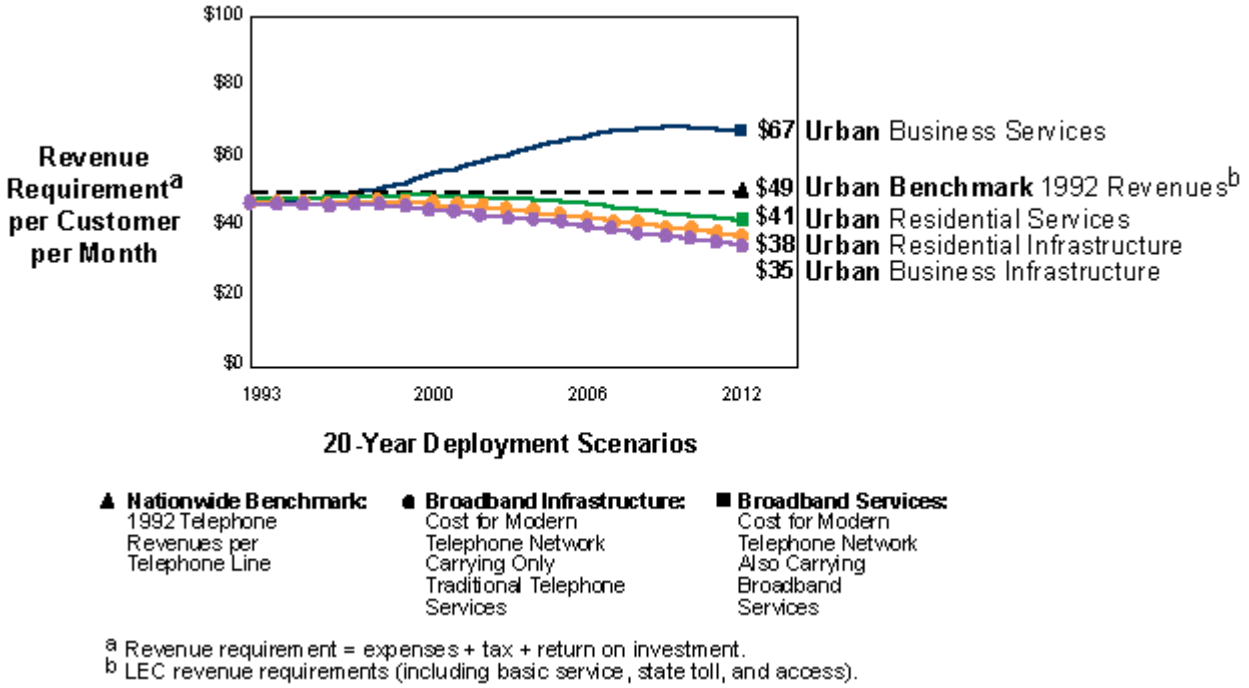
Figure 3
Cost of Local Telephone Company Deployment of Broadband: Nationwide Residential and Business Markets, All Access Lines



[a] Revenue requirement = expenses + tax + return on investment.
[b] LEC revenue requirements (including basic service, state toll, and access).

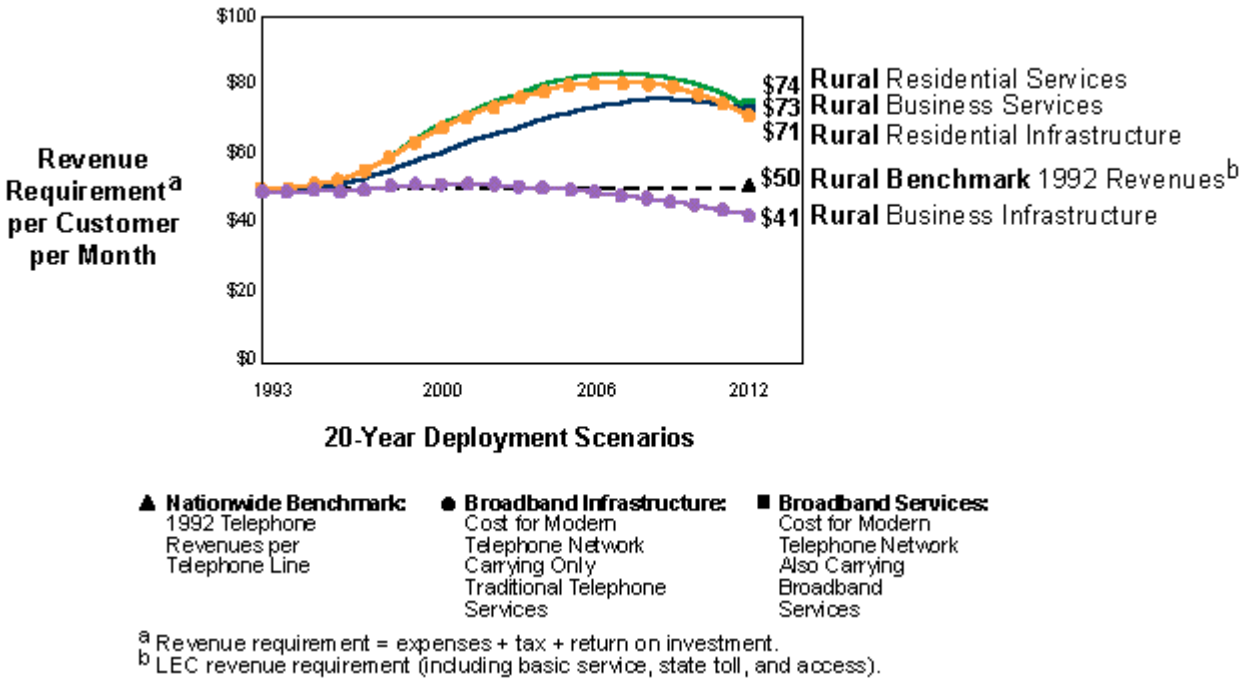
Note: Assumes a 2.35 annual growth in nationwide access lines. For the Broadband Services curve, each year 5% of broadband-capable access lines also become equipped for Broadband Services. The Nationwide Benchmark of $49.98 is a calculated revenue requirement for Tier 1 local exchange carriers (LECs) divided by the number of access lines for Tier 1 LECs. Costs are for all access lines (broadband-capable plus non-converted). This benchmark is an aggregate for both business and residential services. Definitions of business and residential services are different.

Figure 4
Cost of Local Telephone Company Deployment of Broadband: Urban Residential and Business Markets, All Access Lines



Note: Assumes a 2.35% annual growth in nationwide access lines. For the Broadband Services curve, each year 5% of broadband-capable access lines also become equipped for Broadband Services. The Urban Benchmark of $48.81 is a calculated revenue requirement for Tier 1 local exchange carriers (LECs) divided by the number of MSA lines for Tier 1 LECs. This benchmark is an aggregate for both business and residential services. Costs are for all access lines (broadband-capable plus non-converted). Definitions of business and residential services are different.

Figure 5
Cost of Local Telephone Company Deployment of Broadband: Rural Residential and Business Markets, All Access Lines



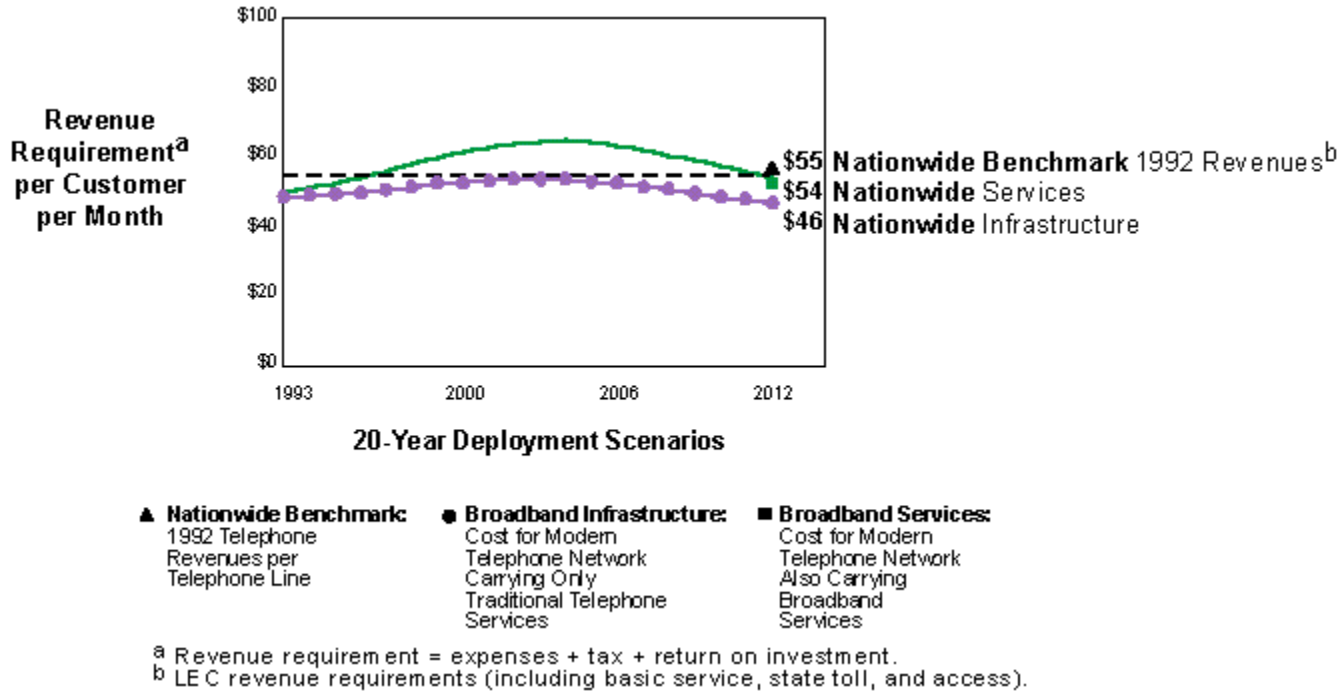
Note: Assumes a 2.35% annual growth in nationwide access lines. For the Broadband Services curve, each year 5% of broadband-capable lines also become equipped for Broadband Services. The Rural Benchmark of $49.79 is a calculated revenue requirement for Tier 1 local exchange carriers (LECs) divided by the number of non-MSA lines for Tier 1 LECs. This benchmark is an aggregate for both business and residential services. Costs are for all access lines (broadband-capable plus non-converted). Definitions of business and residential services are different.

Figure 6
Capital Investment Output Reports: Nationwide Market

		Cumulative Investment, Nationwide: 20-Year Deployment			
		100% Capable, 0% Equipped Broadband Infrastructure		100% Capable, 100% Equipped Broadband Services	
Line:	Investment Categories:	Dollars in Billions:	Percent of Total:	Dollars in Billions:	Percent of Total
1	Loop Electronics	79.6	34.4%	148.7	35.7%
2	Cable and Wire	120.1	51.9%	120.1	28.9%
3	Circuit Equipment	30.5	13.2%	32.4	7.8%
4	Digital Switching	1.1	0.5%	114.6	27.6%
5	Total	231.3	100.0%	415.9	100.0%

Note: Assumes a 2.35% annual growth in nationwide access lines. For the Broadband Services curve, each year 5% of broadband-capable access lines also become equipped for Broadband Services. The Rural Benchmark of $49.79 is a calculated revenue requirement for Tier 1 local exchange carriers (LECs) divided by the number of non-MSA lines for Tier 1 LECs. This benchmark is an aggregate for both business and residential services. Costs are for all access lines (broadband-capable plus non-converted). Definitions of business and residential services are different

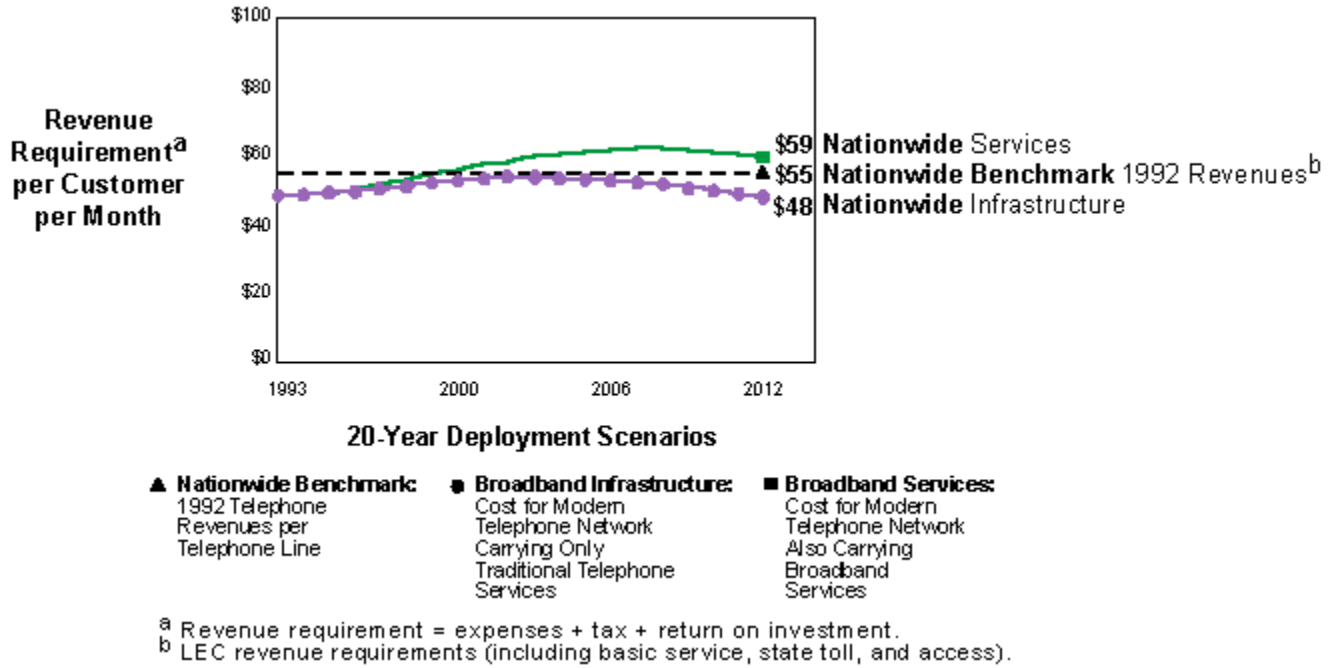
Figure 7
Nationwide Cost Curves (1995) Model, 1993 Assumptions, All Access Lines



Note: Assumes a 3.0% annual growth in nationwide access lines. All broadband-capable access lines for a given year are also equipped to provide Broadband Services. The Nationwide Benchmark of $54.72 is a calculated revenue requirement for Tier 1 local exchange carriers (LECs) divided by the number of access lines for Tier 1 LECs. Costs are for all access lines (broadband-capable plus non-converted).

Source: Current Model and assumptions from Weinhaus, Carol; Pitts, Teresa; *et al., Beyond Future Shock*.

Figure 8
Nationwide Cost Curves: Current Model (1995), 1994 Assumptions, All Access Lines



Note: Assumes a 2.35% annual growth in nationwide access lines. For the Broadband Services curve, each year 5% of broadband-capable access lines also become equipped for Broadband Services. The Nationwide Benchmark of $54.72 is a calculated revenue requirement for Tier 1 local exchange carriers (LECs) divided by the number of access lines for Tier 1 LECs. Costs are for all access lines (broadband-capable plus non-converted).

Source: Current Model and assumptions from Weinhaus, Carol; Makeeff, Sandra; Copeland, Peter; *et al., The Cost of Mandating Technology in Rural Areas.*