Ex. __ (AES-1)

BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

In the Matter of the Pricing Proceeding for Interconnection, Unbundled Elements, Transport and Termination, and Resale	)	DOCKET NO. UT-960369
In the Matter of the Pricing Proceeding for Interconnection, Unbundled Elements, Transport and Termination, and Resale for U S WEST COMMUNICATIONS, INC.	)	DOCKET NO. UT-960370
In the Matter of the Pricing Proceeding for Interconnection, Unbundled Elemetns, Transport and Termination, and Resale for GTE NORTHWEST INCORPORATED	)	DOCKET NO. UT-960371

ATTACHMENT 1

DIRECT TESTIMONY

OF

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March 27, 1997

Depreciation Lives for Telecommunications Equipment:

Review & Update

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Acknowledgments

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Depreciation Lives for Telecommunications Equipment:

Review & Update

Local exchange carriers (LECs) have over $250 billion invested in their networks. Over 80% of this investment falls into three categories—outside plant, circuit, and switching. In each category, tremendous changes are underway which are obsoleting the bulk of existing investment and making necessary large amounts of new investment. Since telephone equipment has traditionally been assigned long depreciation lives, these changes mean that existing equipment will be obsolete, and likely out of service, well before existing investment has been recovered under current regulatory depreciation schedules. This report reviews our assessment of the situation and our recommendations for LEC depreciation lives.

Drivers for Change

There are three highly-interrelated drivers that are driving change in telecommunications: technology, competition, and new services. None of these are fully accounted for in the traditional approach to regulatory depreciation. This section briefly reviews these drivers and how they reinforce each other.

Technology Advance

Advances in technology are providing more efficient and functional ways of offering traditional telephone services, as well as wireless services, video services, and new digital communications. Four of the key technologies are:

- Fiber in the loop (FITL), including any architecture that extends fiber into the distribution portion of the local loop. The last link to the customer may be on fiber, copper pairs, coaxial cable, or wireless.

There are a number of architectures that are under consideration or are being planned. A true consensus has yet to emerge on a single FITL architecture. Continuing changes in technology costs, regulation, business relationships, market forecasts, and market share assumptions probably mean that consensus will be arrived at only gradually. Whatever architecture is chosen, it will displace the vast majority of copper investment.

- Advanced digital switching, especially Asynchronous Transfer Mode (ATM) switching.

The next major switching generation, ATM switching, is optimized to handle all types of traffic on the network efficiently and quickly. Today's digital switches use time division multiplexing to connect continuous streams of digitized voice or data at 64 Kb/s for the duration of a call. This is efficient for low-speed, circuit-switched applications such as voice, but it is unusable or inefficient for high-speed digital applications, especially those with bursty (non-continuous) traffic characteristics. ATM switches, on the other hand, use small fixed-length packets called cells. Unlike conventional packet switches, ATM switches do not introduce significant signal delay (because of the simple cell structure) which means they can be used for continuous, real-time applications such as voice and videoconferencing. However, since ATM uses packet switching, it is also good for bursty data traffic. The ability to handle all types of traffic, at all variable data rates, not only makes ATM an efficient switch, but it is also ideal for networked multimedia applications that use all types of communications.

- Synchronous Optical Network (SONET) transmission on fiber optic systems, including Next Generation Digital Loop Carrier (NGDLC) systems incorporating SONET.

SONET is a new format for organizing information on a fiber optics channel that recognizes the need for integrating different types of traffic on the same pair of fibers. Among its many advantages are standardized optical and electrical interfaces to which all suppliers must adhere. Another is that an individual information stream on a fiber channel can be efficiently separated from the rest of the information on the channel. With a SONET add-drop multiplexer, any signal can be extracted with a single piece of equipment without breaking down the whole signal. SONET add-drop multiplexers are already cost-competitive with asynchronous equipment, and soon will be commodity items that are integrated into almost every piece of circuit (and switching) equipment. This will render redundant much existing circuit equipment, including digital crossconnects and multiplexers.

Further, with SONET, carriers can mix-and-match circuit equipment so that they can use different manufacturers' equipment. This, of course, provides operational and equipment savings, as well as more competition between manufacturers. Later on, SONET interfaces will be built directly into switches, leading to even more equipment savings. NGDLC systems will directly link to switches through SONET interfaces. From the same unit, some channels may be connected to other switches or facilities using a built-in SONET add-drop multiplexer. Circuits could be transferred from one switch to another instantaneously. This will give carriers much more flexibility when it comes to dealing with switch manufacturers. SONET will benefit customers as well as carriers. In addition to the inherent economic benefits of a more efficient network, SONET will provide greater reliability through its support of fiber ring architectures and enhanced response time and flexibility in provisioning new channels.

- High-capacity digital wireless technologies such as Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA).

These digital wireless technologies can multiply the capacity of existing cellular systems by a factor of from three to 10 and will also be utilized with the new personal communications systems. One implication of the increased capacity is the ability to compete more directly with wireline service.

In a nutshell, the benefits of these technologies are reduced operating costs, reduced capital costs, better service, or, in some cases, new services. The technologies are all well-understood and do not require scientific, engineering, or economic breakthroughs to be deployed. There is widespread agreement about their benefits and cost targets. While there is some controversy about the details and timing, there is consensus that the future of telecommunications is built around these technologies.

Competition

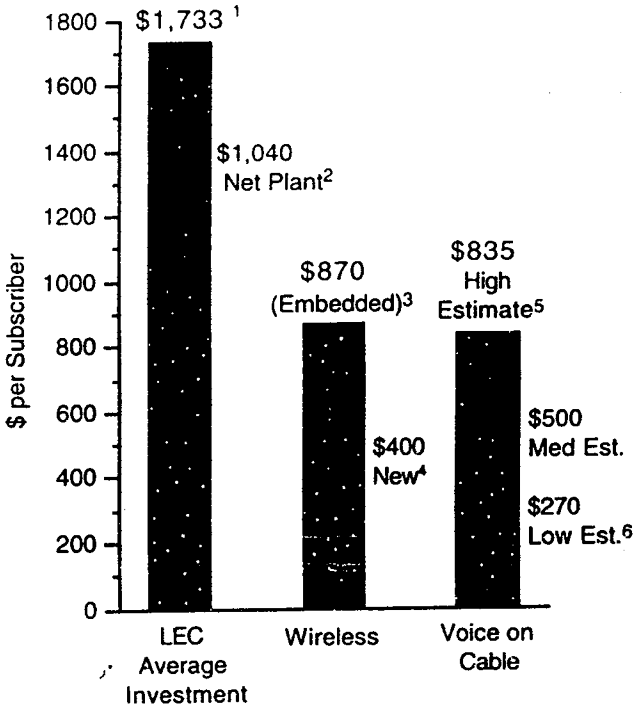
Competition has entered the local exchange business, and it will increase dramatically over the next few years. So far, most local exchange competition has centered on the large business customer. Competitive access providers (CAPs) are already serving large businesses in concentrated areas, and cable television companies are providing alternative access for high-bandwidth services. CAPs are installing the latest, most efficient technology—fiber optics, SONET, and, in cities/ locations where they provide switched services, modern digital switching.

The next competitive arena will be the mass market for voice services. Such competition has already begun in public phones and, in some states, in intra-LATA long distance. Two additional, more pervasive sources of competition are cable television networks and wireless networks, specifically cellular and personal communications services (PCS). Technologies are emerging that will allow voice to be added to state-of-the-art cable systems at a cost that is less than on copper pairs. On a per-subscriber basis, cellular technologies are already less costly than wireline. With the new high-capacity digital wireless technologies, such as TDMA and especially CDMA, wireless technologies will also be less costly on a per-minute of use basis. Exhibit 1 illustrates some of these cost comparisons.

Because they are more efficient, the new technologies offer very substantial cost advantages to new entrants in local telecommunications. These new entrants can invest in the most efficient modern equipment without regard to an embedded infrastructure such as the LECs have. This, in turn, will pressure LECs to adopt new technology quickly in order to stay competitive. Thus, competition reinforces the technology drivers and magnifies the obsolescence of the old technology.

Exhibit 1

Investment Per Subscriber



Source: USTA Engineering Subcommittee on Depreciation

[1] Industry investment of $260 billion and 150 million access lines at year-end 1993.

[2] Net plant assumes 40% depreciation reserve (industry average at year-end 1993).

[3] Total wireless industry investment divided by number of customers (source: CTIA, year-end 1993).

[4] Annual wireless industry investment increase divided by customers gained (source: CTIA, year-end 1993).

[5] Estimate by Hatfield Associates, Inc. in a 1994 study for MCI, Alternative Distribution and Access Technologies. Includes land and buildings, switch, network interface unit, backhaul, and customer connection (similar to fee paid by cellular to sales agent, $320).

[6] Estimate by David P. Reed in "The Prospects for Competition in the Subscriber Loop: The Fiber-to-the-Neighborhood Approach," presented at the 21st Annual Telecommunications Research Policy Conference (September 1993). It represents costs allocated to telephony for upgrading a cable system for interactive TV and telephony.

New Services

The third driver is the impending emergence of digital communications services for the mass market. These services will support both television and computer-based applications requiring digitized transmission of text, audio, and still and moving images. The applications for these services include advanced fax, computer-based imaging, LAN interconnection, videoconferencing, interactive multimedia, video on demand, and interactive television. Today, the market for digital communications services for these applications is relatively small: however, the potential for growth is tremendous, especially when these services are extended beyond large business customers.

Ultimately, the telephone network will provide full broadband, multimedia communications services based on three of the technologies we have mentioned: fiber optics, SONET transmission, and ATM switching. Along the way, intermediate steps will include narrowband Integrated Services Digital Network (ISDN) and video on demand services. Since some of the new services blur the traditional distinctions between telephony, television, publishing, information systems, and computing, they foster a new type of competition focused on the convergence of these industries. In this environment, competitive advantages belong to those companies that can deliver a package of diverse services for the least cost. As it happens, the new technologies allow delivery of multiple services at overall costs that are comparable or less than the traditional delivery mechanisms for the individual services.

Impacts on Depreciation Lives

Alone, any one of these drivers would cause significant change in the deployment of technology. Together, they are forcing unprecedented change that is rendering most of today's telephone network obsolete. Although satisfactory for voice services, today's network is expensive to operate and offers limited functionality in terms of mobility and digital services. It was optimized and constructed for the age of electromechanical and analog switching and copper cable, an age which for a decade has been giving way to digital switching and fiber optics. Much of the equipment placed in the last decade is becoming obsolete in the face of new technologies such as SONET and ATM. Thus, if LECs are to remain viable, they must rebuild their networks—sooner rather than later. This necessitates continued, massive investment in new technology that requires much shorter lives for existing investment than are currently prescribed by regulators.

Weaknesses in Regulatory Depreciation Methods

The traditional method for estimating depreciation lives is to examine mortality data for older vintages and assume that all vintages will experience the same age-dependent characteristics. For example, if 60% of the units of a particular technology installed in 1983 were still in service in 1989 (six years later), we would assume that 60% of the units installed in 1990 would still be in service in 1996 (again, six years later). (This greatly over-simplifies, but captures the basic idea.) The assumption of age-dependent retirements reflects a situation where wear-out or breakdown drives the replacement process. Under this model, new technology (or perhaps a new unit of old technology) replaces old technology only when the old technology wears out or breaks. This is an accurate model for some situations; for example, it reflects the way most companies replace motor vehicles.

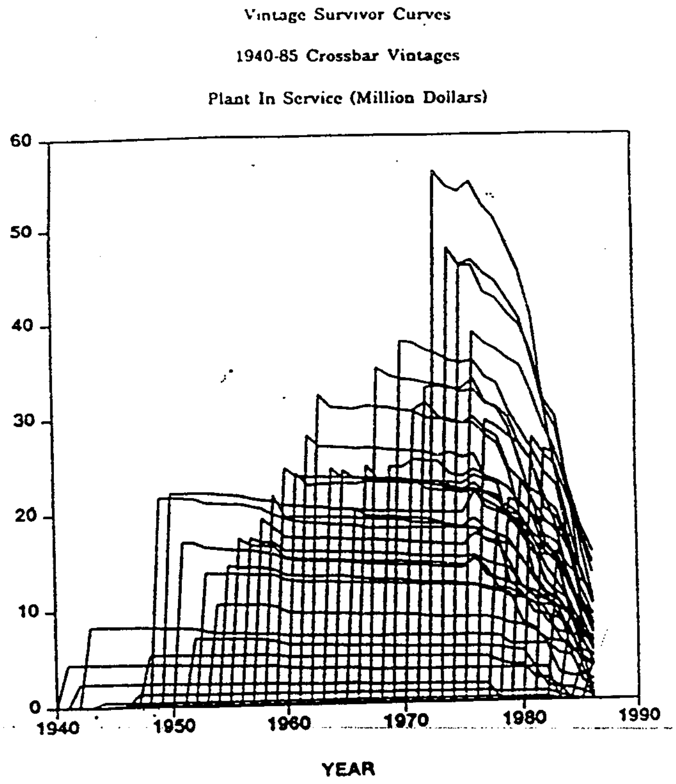
Today, however, technological obsolescence is a major cause of retirements in telecommunications for switching and circuit equipment, and is also expected to be for outside plant in the near future. (Other drivers—competition and new services—are largely reflected in this driver.) Mortality analysis alone is not appropriate in such a situation. This is made clear in Exhibit 2, which plots the vintage survivor curves for crossbar switching. These are similar to normal survivor curves except that a separate investment life cycle is shown for each vintage of equipment. Note the "avalanche effect" between 1975 and 1980. During this period, all vintages experienced sudden and simultaneous retirements, as electronic switching was rapidly adopted.

One can also see from the avalanche curves that, when technological obsolescence is the major driver for retirements, there is no such thing as a constant service life. Equipment purchased late in a technology generation will have a much shorter life than a piece of equipment purchased earlier. Further, the expected service life of equipment purchased late in the cycle is roughly the same as the average remaining life of existing equipment. These observations are contrary to mortality-based depreciation, but they reflect reality.

Most important, until the avalanche begins, life estimates for the old technology using mortality-based analysis will be based on an extension of the pre-avalanche trend and, thus, will be way too long. Not only will the life estimates be wrong, but they will be wrong right up to the moment the avalanche begins. To use a different metaphor, this is like paddling a rowboat without ever looking forward. You are over the falls before you know anything is wrong!

Exhibit 2

Avalanche Curves



Source: Bellcore

The original replacement technology for crossbar switching was analog stored program control (ASPC) switching, first introduced in the mid-to-late 1960s. Note that the avalanche of crossbar retirements begins in about 1975, more than five years after the introduction of the new technology.

Also note that very large amounts of investment were made in the old technology very late in its life cycle, even after the new technology was available. Although this behavior may seem odd, it is typical of many technologies and can often be perfectly rational. (For example, millions of 486 personal computers have been sold since the introduction of the replacement technology, the Pentium.) It can result from several factors:

(1) The need to maintain existing equipment and service levels.

(2) Restrictions on the availability of the new technology.

(3) High relative costs for the new technology early in its life cycle.

(4) An inherent bias toward the existing technology.

However, we must keep in mind that the last purchases of old technology will have especially short lives.

An important implication of this phenomenon is that recent investment patterns in the old technology tell us little about the likely adoption of new technology, even in the near future. Purchase volumes of the new technology may be smaller than those of the old technology almost to the time the avalanche begins.

Using Technology Forecasting to Estimate Depreciation Lives

Fortunately, there are reliable methods that allow us to forecast future technology changes and, thus, depreciation lives. Developed and tested over many years in telecommunications and other industries, these methods have proven to be very reliable for forecasting. Their basis lies in an understanding of the process of technology change and the use of available data to produce quantitative forecasts.

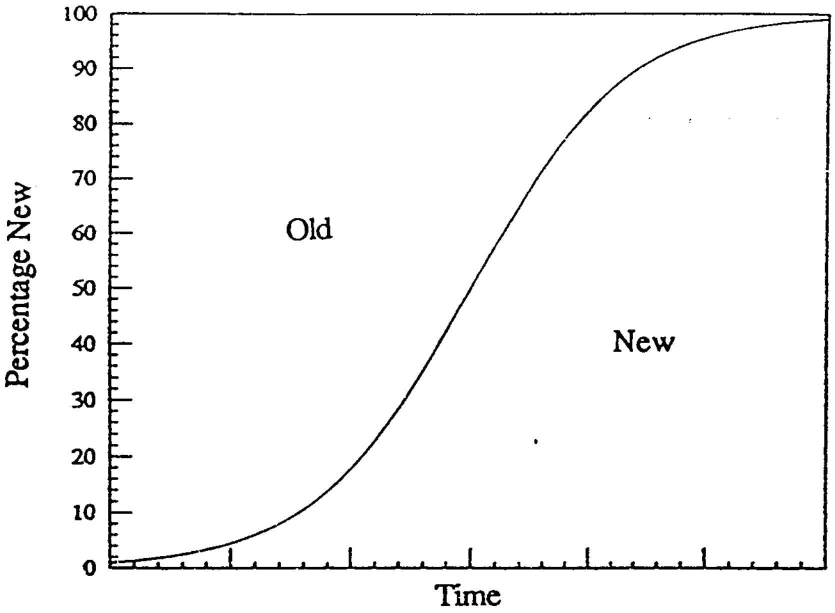
One technology forecasting method, substitution analysis, has been proven effective in projecting the adoption of new technologies and the obsolescence of old technologies. Substitution refers to the displacement of an established technology by a newer technology when the new technology provides substantially improved capabilities, performance, or economies. With substitution, technological superiority of the new technology—not wear-out—is the driver for replacement.

With substitution analysis, we examine patterns of technology substitution. The pattern is remarkably consistent from one substitution to another, and is characterized by an S-shaped curve when the market share of the new technology is plotted over time. Exhibit 3 shows the S-shaped curve for the Fisher-Pry model. Of the several substitution models available, in general, we have found the Fisher-Pry model—and its extensions, notably, multiple substitution models based on the same principles—to be the most useful for forecasting. The adoption of a new technology starts slowly because, when it is first introduced, a new technology is usually expensive, unfamiliar, and imperfect. The old technology, on the other hand, has economies of scale and is well-known and mature. As the new technology improves, it finds more and more applications, it achieves economies of scale and other economic efficiencies, and it becomes generally recognized as superior. The old technology, because of its inherent limitations and falling market share, cannot keep up. The result is a period of rapid adoption of the new technology, beginning at the 10% to 20% penetration level. This corresponds with a period of rapid abandonment of the old technology, i.e., the avalanche. Toward the end of the substitution, adoption of the new technology slows down again as the last strongholds of the old technology are penetrated.

Since the pattern of how a new technology replaces an old one is consistent, we can apply the pattern to a technology substitution in progress, or one just beginning, to forecast the remainder of the substitution and estimate the end date for the old technology. We can apply substitution analysis even in cases where the substitution has yet to begin by using appropriate analogies, precursor trends, or evaluation of the driving forces. More information on the Fisher-Pry model and its application is provided in Attachment 1.

Exhibit 3

The Fisher-Pry Model



Source: Technology Futures, Inc.

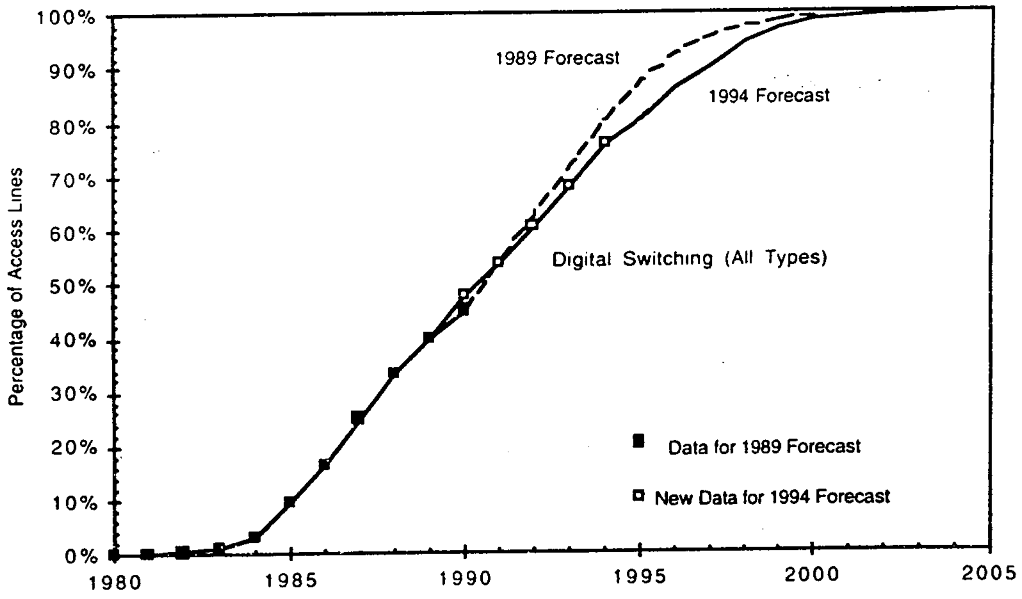
Experience with the Fisher-Pry Model

Although no forecasting method is perfect, our experience with the model has been excellent. Occasionally, we compare prior forecasts with subsequent data and new forecasts. These comparisons demonstrate the accuracy of the model within reasonable tolerances.

An example is a forecast that Technology Futures, Inc. (TFI) prepared in 1989 for the substitution of digital switching for analog switching by major LECs. Exhibit 4 shows the 1989 forecast, and the solid markers show the data available for the forecast. The actual data for subsequent years, shown by the hollow markers, traces the 1989 forecast within about 10%, and almost exactly matches the projected end date. Our earlier forecasts, dating back to the mid-1980s, were less perfect regarding the year-by-year pattern, but accurately forecast the end-date for analog switching to be between 1997 and 2001. This was at a time when many experts thought there would be no retirements at all of analog ESS switches before 2000!

Exhibit 4

Comparison to 1989 Digital Switching Forecast



Source: Technology Futures, Inc.

Comparison of Mortality Analysis and Substitution Analysis

Substitution analysis provides better indicators of lives than mortality-based methods because substitution analysis recognizes that technological obsolescence is the major driver for retirements. As previously noted, analysis of recent retirement and investment data could not have predicted the rapid retirements of electromechanical switches between 1975 and 1980 (the avalanche shown in Exhibit 2). Using historical data, a substitution analysis performed as early as 1970 would have predicted the avalanche. This is because substitution analysis recognizes the early adoptions of the new technology, in this case analog SPC switches, years before significant quantities of the old technology are retired—and even when large investments in the old technology are still being placed. The early adoptions, corresponding to the first, relatively flat part of the S-shaped substitution curve, are often for growth applications that do not cause significant retirements.

However, they are a *precursor* for later replacement programs that do result in retirements. This is one reason why substitution analysis can predict the edge of the waterfall. The steep part of the S-shaped curve, where new technology is placed very rapidly, corresponds to the avalanche of retirements.

The example shown in Exhibit 4 again illustrates the power of technology forecasting. Substitution analyses done in the mid-to-late 1980s predicted the avalanche that is burying the analog ESS accounts of the major LECs today.

Another important point is that substitution analysis measures technology in terms of physical units in use. For example, we forecast access lines in service or equivalent circuits in service. Beside measuring in physical units rather than dollars, substitution analysis reflects whether a unit of investment is useful as opposed to whether it is retired. On fundamental principles, usefulness is the better depreciation measure because it reflects the productive value of an asset. Also, because of the potential lag between the end of an asset's useful life and its retirement, retirements are typically a late indicator of major changes in an account. Following the avalanche curves, obsolescence-based retirements show up only after the story is almost over. Measuring units in use, on the other hand, provides a leading indicator.

Why Using Technology Forecasting for Life Estimation Is So Important Now

Throughout the history of telephony, technology advance has caused the replacement of old technology, as evidenced by previous avalanche curves and S-shaped substitution curves. However, there are several things that make things different now. First, we are in a period where rapid advances in microelectronics and fiber optics technology are reshaping telecommunications economics at an unprecedented pace. Second, these changes are impacting all parts of the network simultaneously, leading rapidly to a broadband network architecture that is fundamentally different than today's. Third, there are two other drivers, competition and new services, that reinforce the already strong technology driver. The result will be simultaneous avalanche curves occurring in all major investment categories during the late 1990s and early 2000s.

Historically, avalanche curves have been recognized by the regulatory depreciation process after the fact since traditional depreciation analysis provides no way to predict them. Since avalanches usually reflect retirements that occur before the end of the equipment's prescribed depreciation life, they create depreciation reserve deficiencies. In the past, these reserve deficiencies have been recovered by amortizations over future years. This approach worked satisfactorily in the days when avalanches were the exception rather than the rule, and when the monopoly structure of the industry allowed reserve deficiencies to be recovered from future ratepayers. However, in the new environment, this approach is less likely to work. Capital must be recovered while the investment is still useful—before it is retired. The competitive environment will not allow LECs to recover investment in both old and new technologies simultaneously. This means that lives must be accurately estimated as early as possible—before the avalanche begins, and even before explicit replacement programs are in place. This is why using technology forecasting to predict depreciation lives is so important.

TFI Telecommunications Technology Forecasting Studies

Technology Futures has been applying technology forecasting to the telecommunications industry since 1984. Much of our telecommunications work has been supported by the Telecommunications Technology Forecasting Group (TTFG), an industry association of major LECs in the United States and Canada which was formed in 1985. The mission of the TTFG is to promote the understanding and use of technology forecasting techniques, economic evaluators, and engineering models to predict and support the continued evolution of the telecommunications network. Under TTFG sponsorship, TFI has produced numerous major studies on telecommunications technology adoption in a span of 10 years, long enough to establish a track record. The list is shown in Attachment 2.

The TFI studies fall into three general categories. First is a series of industry studies on the adoption of new technology in the telephone network. We started doing these studies in 1985 and have issued updates over the years. The most recent report, *Transforming the Local Exchange Network: Analyses and Forecasts of Technology Change*, was issued in 1994 and covers switching equipment, outside plant, and circuit equipment. These studies provide quantitative forecasts of the adoption of new technology—and the replacement of old technology—in future years.

Second is a set of seven studies completed between 1991 and 1993 on the need for and adoption of new digital telecommunications services. In these studies, we assessed the drivers and benefits, as well as the constraints, of new services to provide applications such as advanced fax, electronic imaging, interactive multimedia, local area network interconnection, videoconferencing, and interactive television. We concluded that there is a potential mass market for these applications, and that the widespread availability of digital services is required to serve them. We then developed quantitative forecasts of demand over time for digital services at various data rates. The results of the studies were summarized in our 1993 report *New Telecommunications Services and the Public Telephone Network.*

Third are several studies on the effect of competition on the existing investment in the local exchange network. These studies quantify the revenue losses in voice services that are likely due to competitors using technologies that make obsolescent today's copper network. The most recent is our 1995 report, *Wireless and Cable Voice Services: Forecasts and Competitive Impacts.*

A unifying conclusion from these studies is that regulatory depreciation lives are much too long, especially given the climate of rapid change we are entering.

Life Estimates for Telecom Equipment

The remainder of this report reviews the TFI industry forecasts for the major categories of LEC network equipment: outside plant, circuit, and switching. Since the same basic drivers are present across the nation (technology advance, competition, and the need for new services), the industry perspective is generally applicable to individual companies. The forecasts are detailed in *~~Transforming the Local~~ Exchange Network*. The estimated average remaining lives (ARLs) reported herein have been updated to January 1, 1995 from the January 1, 1994 values that were reported in the referenced document. Tabular data for the forecasts are provided in Attachment 3.

Metallic Cable

The outside plant is traditionally split into underground, buried, and aerial accounts. From the viewpoint of cable placement and wear-out, this is a logical categorization: but when technological obsolescence is the driver for change, the categorization is less useful. In applying technology forecasting, we have, instead, distinguished between interoffice, feeder, and distribution plant, which are spread among the three traditional accounts.[1] We chose this approach because technology is being adopted differently and at different times in the interoffice, feeder, and distribution parts of the exchange network.[2] Also, some of the driving forces of change are different.

Outside Plant—Interoffice Cable

At year-end 1993, the interoffice plant was 96% digital and 74% fiber, as measured by circuits in use.[3],[4] Thus, there is relatively little metallic investment still being used in the interoffice environment. Almost all new investment is fiber and the metallic carrier share has declined steadily. Exhibit 5 shows the technology shares over time. Our forecasts indicate that, for the industry, the interoffice network will be almost 100% fiber by 2000.

Our forecast for the adoption of fiber, and the displacement of non-fiber facilities, is based on a multiple substitution analysis of historical data through year-end 1993 and planning data through year-end 1995.[5] For interoffice copper, the analysis indicates an ARL of 2.9 years as of 1/1/95.[6]

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[1] *Interoffice* facilities connect telephone company central offices (where the switches are located) with each other. *Feeder* facilities are cables that extend from a central office toward the neighborhoods and business areas served by the central office. A typical feeder cable usually serves a large number of customers. The *distribution* network extends from the termination of the feeder facilities to residences and businesses.

[2] For example, most interoffice facilities today are fiber optic systems, while most feeder facilities are provided on copper cables. However, the use of fiber optics in the feeder network is growing rapidly. In the distribution network, copper cable is by far the most common technology, although fiber optic systems are beginning to be adopted.

[3] To be more precise, our units are "equivalent voice-frequency circuits in use," although we usually just refer to them as "circuits." For example, a voice frequency copper circuit on two or four wires counts as one circuit. Each voice frequency equivalent circuit in use on a carrier system is counted as one circuit. Both switched and dedicated circuits are included. For data services, each 64 Kb/s is considered to be equivalent to one circuit. Thus, a leased DS1 line (1.544 Mb/s) is counted as 24 circuits.

[4] *Source*: Year-end 1993 ARMIS data reported to the FCC.

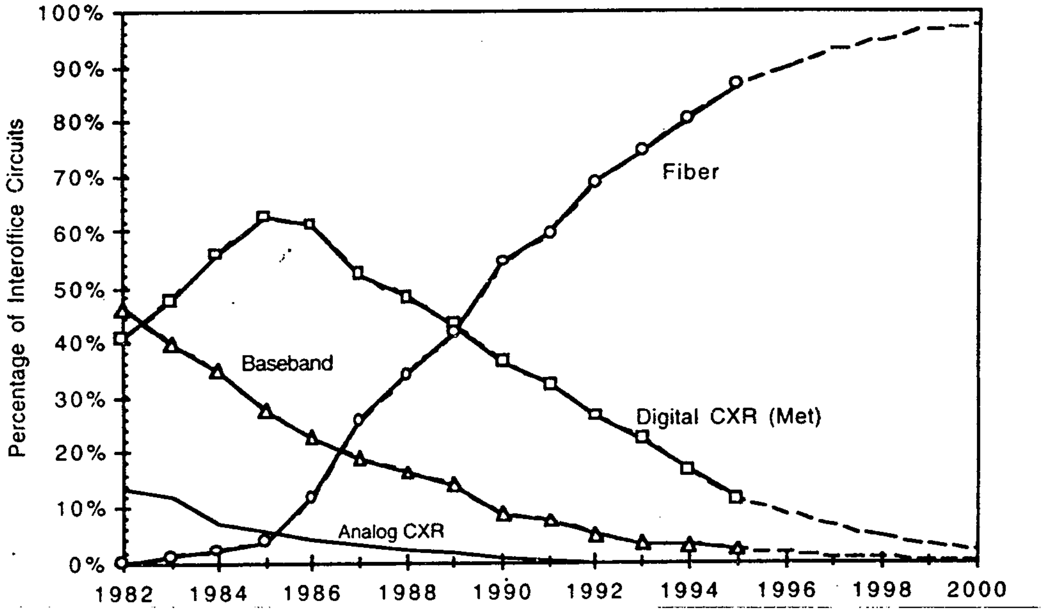
[5] The historical data for 1980-1989 is from TFI files, the historical data for 1990-1993 is from ARMIS reports filed with the FCC, and the planning data for 1994-1995 is the weighted average from the seven LECs (representing over 90 million working access lines in 1993) that provided us planning data. (We used the planning data in our forecast because we have generally found that the first several years of planning data is reliable and improves mid- to long-range forecasts.)

[6] See Table 3.1 in Attachment 3 for ARL computations.

Outside Plant—Feeder Cable

In the feeder plant, Digital Loop Carrier (DLC) systems have been reducing the need for copper pairs for many years. Both metallic-based and fiber-based DLC systems have been adopted, although fiber DLC systems are beginning to dominate in the industry. The replacement of both voice frequency copper cable and metallic-based DLC systems by fiber optic systems characterize future technology change in the feeder plant.

Exhibit 5
Interoffice Technology Shares



Source: Technology Futures, Inc.

Exhibit 6 shows the percentage of access lines served by each of the major technology types for the industry. The forecast is based on a multiple substitution analysis of historical and planning data, shown by the markers.[7] Between 1995

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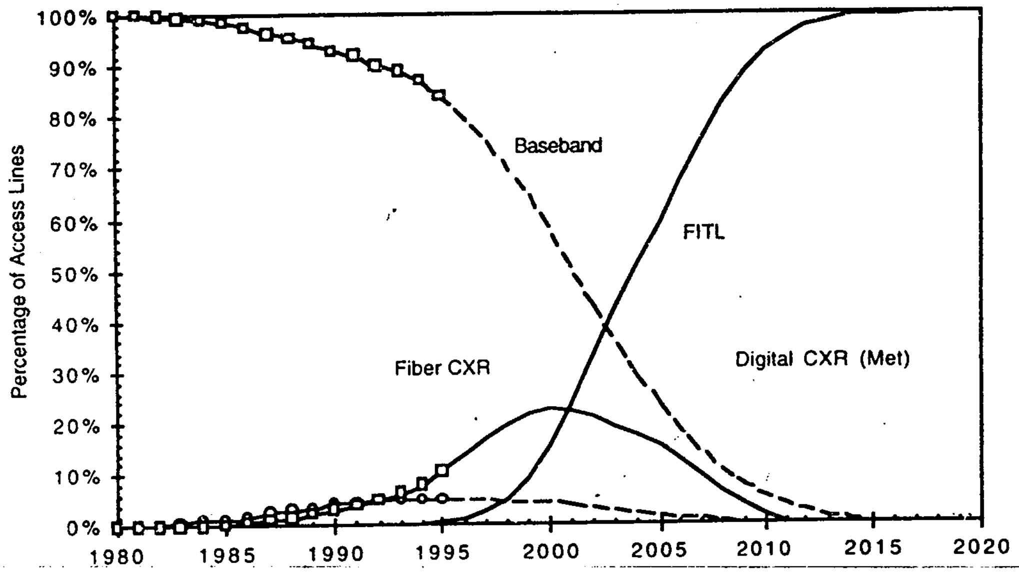
[7] The historical data for 1980-1989 is from TFI files, the historical data for 1990-1993 is from ARMIS reports filed with the FCC, and the planning data for 1994-1995 is the weighted average from the eight LECs (representing over 100 million working access lines in 1993) that provided us

and 2000, conventional fiber-based DLC will continue to grow, reaching a peak at about 23% of access lines by 2000. This period will also see the rapid growth of fiber in the loop (FITL) systems, which, under the industry middle scenario (discussed in the next section), are forecast to serve 15% of access lines by 2000. After 2000, FITL systems are forecast to rapidly displace all other types of feeder technologies, serving 50% of access lines by 2004, 90% by 2010, and essentially all access lines by 2015. Based on these results, an industry ARL of 7.0 to 7.8 years (as of 1/1/95) is expected for feeder metallic cable, depending on which FITL scenario is chosen.[8]

Exhibit 6

Feeder Technologies—Percentage of Access Lines



Source: Technology Futures, Inc.

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planning data. While DLC will continue to substitute for feeder copper. FITL systems will also impact feeder copper facilities in the same manner it will distribution facilities. With very few exceptions. FITL will require fiber feeder. Thus, we incorporated the FITL adoption into the feeder multiple substitution analysis.

[8] See Table 3.2 in Attachment 3 for ARL computations.

Outside Plant—Distribution Cable

We use the term FITL to refer to any architecture that extends fiber to an area of no more than several hundred customers; the last link to the customer may be on copper pairs, coaxial cable, fiber, or wireless. There are a number of architectures that are under consideration or are being planned. A true consensus has yet to emerge on a single FITL architecture. Continuing changes in technology, costs, regulation, business relationships, market forecasts, and market share assumptions probably mean consensus will be arrived at only gradually. Whatever architecture is chosen, it will displace the vast majority of copper investment.

Our analysis of distribution facilities includes three scenarios for the adoption of FITL. Each of these scenarios is based on composite forecasts of the demand for wideband and broadband digital services. The "early" scenario assumes that fiber is deployed rapidly to meet the emerging demand for new wideband services at 1.5 Mb/s or similar data rates. The "late" scenario assumes that wideband services are deployed on copper pairs using interim copper technologies such as Asymmetrical Digital Subscriber Line (ADSL) and High-speed Digital Subscriber Line (HDSL), and that fiber is not rapidly adopted until the demand for broadband services (45 Mb/s and above) emerges. The "middle" scenario is an average of the two others.

Exhibit 7 shows forecasts for the demand for wideband and broadband services from TFI's recent *New Services Study*.[9] Also shown is the required fiber deployment under the early and late scenarios, respectively. The relationship between deployment (which determines service availability) and demand is derived from a prior TFI analysis of the historical availability and adoption of four TV-based services.[10] Exhibit 8 graphically illustrates the averaging process used to obtain the middle scenario from the other two.

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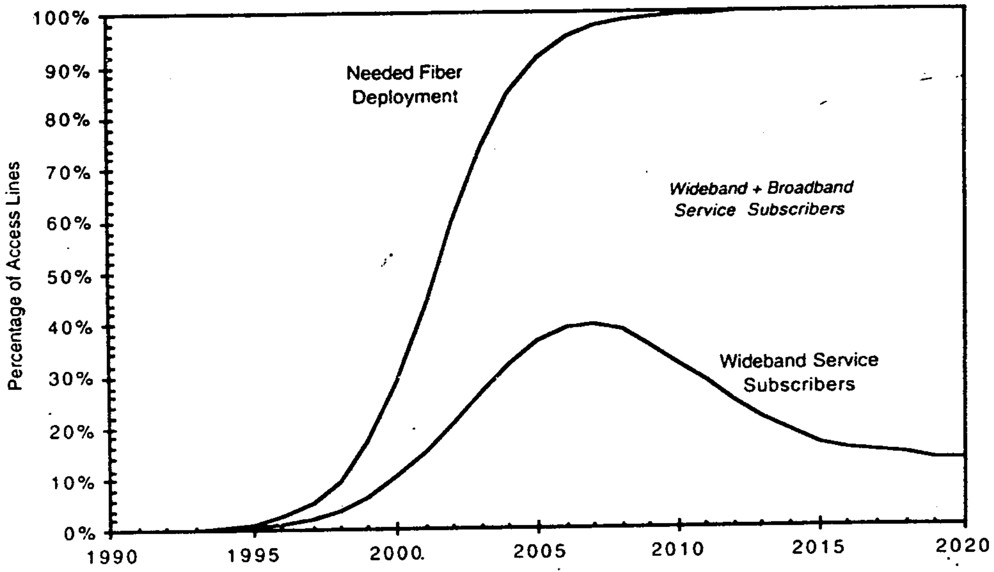
[9] L. K. Vanston, W. J. Kennedy, and S. El-Badry-Nance, *A Facsimile of the Future: Forecasts of Markets and Technologies* (1991); L. K. Vanston, S. El-Badry-Nance, W. J. Kennedy, and N. E. Lux, *Computer-Based Imaging and Telecommunications: Forecasts of Markets and Technologies* (1992); J. A. Marsh and L. K. Vanston, *Interactive Multimedia and Telecommunications: Forecasts of Markets and Technologies* (1992); B. R. Kravitz and L. K. Vanston, *Local Area Network Interconnection and Telecommunications* (1992); L. K. Vanston, J. A. Marsh, and S. M. Hinton, *Video Communications* (1992); L. K. Vanston, J. A. Marsh, and S. M. Hinton, *Telecommunications for Television/Advanced Television* (1992); and L. K. Vanston, *New Telecommunications Services and the Public Telephone Network* (1993) (Austin, TX: Technology Futures, Inc.).

[10] Vanston, Marsh, and Hinton, *Telecommunications for Television/Advanced Television*, pp. 123-144; and Vanston, *New Telecommunications Services and the Public Telephone Network*, pp. 45-52.

The middle scenario represents a balancing act for the LECs. If they overinvest in upgrading copper, they risk entering the next century with an obsolete network after having sunk large amounts of money into equipment to enhance the copper technology. On the other hand, they cannot get fiber to everyone simultaneously, and, even if they could, it might not be the best plan financially. The middle scenario avoids the two extremes, with wideband services being provided on copper in the early years, then migrating to fiber as demand increases and costs continue to fall.

Exhibit 7

Distribution Fiber to Meet New Services Demand



Source: Technology Futures, Inc.

Exhibit 7 (Continued)

Distribution Fiber for Broadband Services

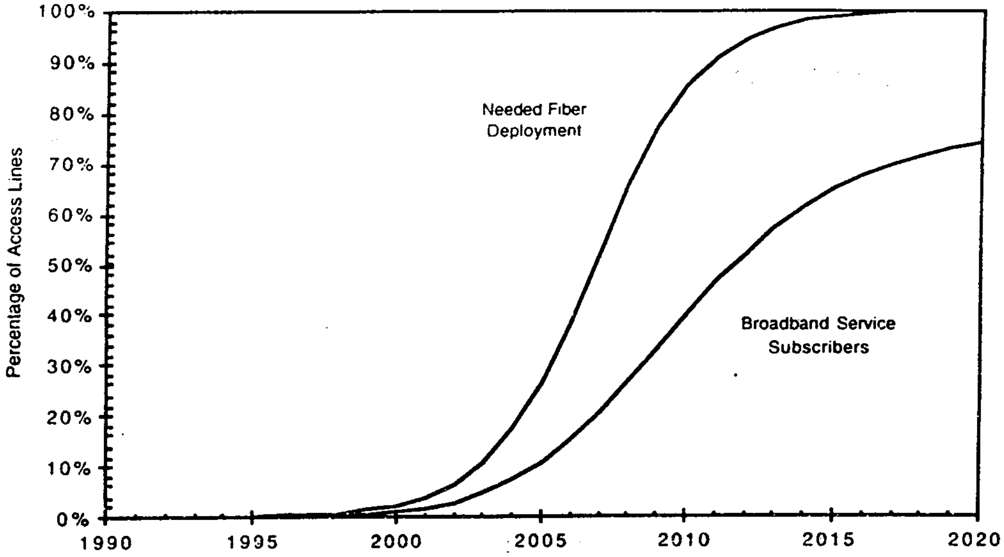
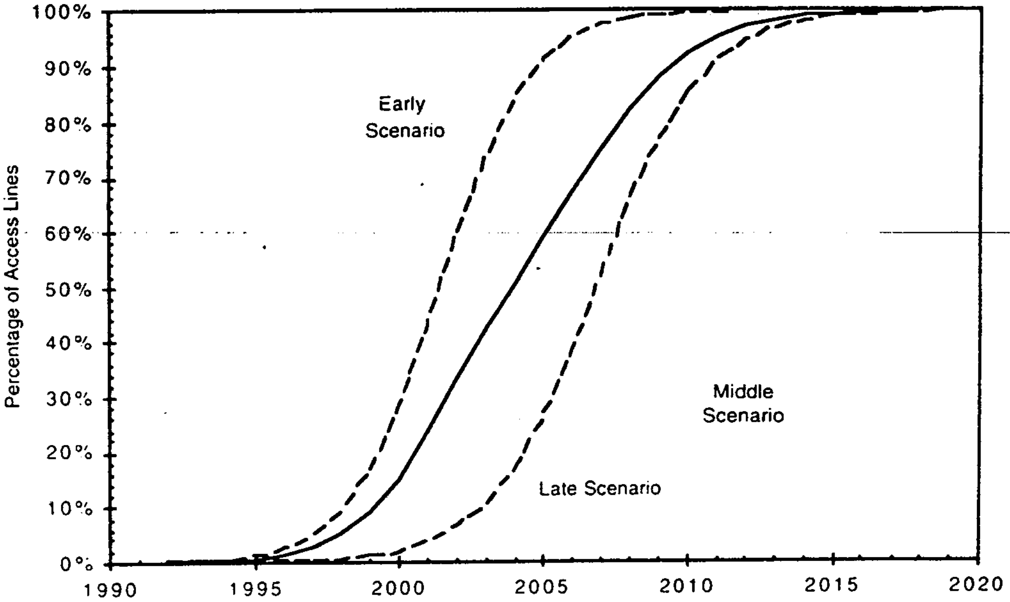


Exhibit 8

The Adoption of Distribution Fiber—Three Scenarios



Source: Technology Futures, Inc.

Adopting fiber more slowly than in the middle scenario would require too large of an investment in ADSL/HDSL and divert excessive resources away from the preferable, long-term technology—FITL. With the competition deploying more efficient technology and offering higher-quality services, this would be a dangerous course. For this reason, we believe that the middle scenario implies the maximum rational deployment of interim technologies and that the late scenario is not a reasonable choice.

However, this does not mean that the middle scenario is necessarily the best choice either. For companies that want to realistically compete in the provision of standard cable television services, as opposed to what has been called VCR-quality interactive services, the early scenario is better. Also, regardless of cable television services, many companies will adopt fiber strategies that will be much closer to the early scenario because, given the increasingly competitive nature of the industry, this is a less risky strategy. For these reasons, we believe that the likely industry FITL adoption pattern will fall between the early and middle scenarios.

The result is an industry ARL of 10.2 years (as of 1/1/95) for copper distribution facilities for the companies that adopt fiber according to the middle scenario. Companies that aggressively adopt fiber optics will experience an ARL of about 7.5 years.[11] We believe that competitive forces in the industry will tend to move the industry as a whole closer to the early scenario. These estimates do not take into account the impact of competition. TFI's 1995 competitive impact study showed that competition from wireless technologies and cable television could reduce remaining economic lives for copper cable to between two and five years, even under the average fiber adoption scenario.[12]

Metallic Cable, Composite Lives

Ignoring competition, we recommend average remaining lives of 2.9 years for interoffice copper, 7.0 to 7.8 years for copper feeder, and 7.5 to 10.2 years for distribution. About 5% of current metallic outside plant investment is in interoffice facilities, with the remainder divided equally between feeder and distribution. Thus, a composite ARL for copper outside plant should be between 7.0 and 8.7

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[11] See Table 3.3 in Attachment 3 for ARL computations.

[12] L. K. Vanston and C. Rogers, *Wireless and Cable Voice Services: Forecasts and Competitive Impacts* (Austin, TX: Technology Futures, Inc., 1995).

years.[13] For a typical company, this would correspond to a projection life of between 14 and 16 years for the installed base of equipment. A range of projection lives are provided since a specific projection life corresponding to the industry ARL depends upon age, distribution, and curve selection.

As an example, underground cable is mostly interoffice and feeder, and an ARL of 6.6 to 7.3 years is recommended for that account.[14] For a typical company, this ARL corresponds to a projection life of between 13 and 15 years for the installed base of equipment. It should be noted that the projection life depends on curve assumptions and the average age of plant, which will be unique for each company.

Lives for Fiber Cable

Although there continue to be significant technological improvements in fiber optic cable, it is not yet clear how much of today's single-mode fiber will be replaced when superior technology becomes available. Much of the multimode fiber installed in the early days of fiber has been replaced with single-mode fiber. With such an historical precedent, we cannot rule out technology-driven replacement of fiber cable. However, with the exception of the multimode to single-mode transition, upgrades to existing fiber systems have concentrated on the associated electronics. For this reason, we did not apply the same type of substitution analysis that we did for the other accounts. This is not to say, however, that fiber investment will have especially long lives.

As identified by GTE Labs and Bellcore, there are four major factors impacting fiber lives: technological obsolescence, topological obsolescence, mechanical degradation, and optical degradation. Technological obsolescence is to be expected even if the successor technology is not obvious today. We have already seen one generation of fiber optics be replaced, as multimode fiber made way for single-mode fiber. Also, manufacturers continue to improve the basic properties of fiber such as flexibility, strength, clarity, transmission quality, reflectivity, refractivity, and durability. Topological obsolescence is where the location, routing, sizing, or architecture of a fiber installation later proves wrong. Finally, fibers eventually will

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[13] This is a weighted average. For the lower value: 5% × 2.9 years + 47.5% × 7.0 years + 47.5% × 7.5 years = 7.0 years. For the higher value: 5% × 2.9 years + 47.5% × 7.8 years + 47.5% × 10.2 years = 8.7 years.

[14] This is a weighted average computed from the relative investments in feeder and interoffice facilities. For the lower value: 10% × 2.9 years + 90% × 7.0 years = 6.6 years. For the higher value: 10% × 2.9 years + 90% × 7.8 years = 7.3 years.

crack or "go dark" with age, causing degradation in transmission capability. Although more careful fiber specification and installation has improved fiber lives, eventual wear-out is still a factor.[15] Putting these factors together, the best available technical judgment indicates that the projection life of fiber should be 20 years and that anything more puts the recovery of capital in jeopardy.[16]

Because of competition, any investment in the local exchange network now has an element of risk. The investment and accounting communities must reflect this risk in evaluating assets.[17] Although, from a technological viewpoint, a projection life of 20 years is appropriate, there should be a downward adjustment for the risk factor. Obviously, the appropriate amount involves some judgment that strays from the realm of both mortality analysis and technology forecasting, but five years may be a reasonable adjustment. Thus, a life of 15 to 20 years is recommended, depending on whether the risk factor is considered.

Lives for Digital Circuit Equipment

The digital circuit equipment account includes a variety of different equipment types, some very modern and some quite old and nearing obsolescence. However, virtually *all* circuit equipment will be impacted by SONET technology. Thus, forecasting the adoption of SONET allows us to calculate an upper bound on the productive life of any type of circuit equipment.

Exhibit 9 shows our forecasts of the percentage of capacity on SONET for the interoffice and loop environments, respectively. These forecasts are based on the Fisher-Pry model applied to estimates and planning data from nine LECs, shown by the hollow boxes. By 2005, essentially all currently-deployed digital circuit equipment will have been replaced by SONET equipment. Combining the interoffice and loop forecasts implies a weighted ARL for digital circuit equipment of

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[15] The physical properties of fiber are very different from those of copper, and their physical lives are affected by different factors. Thus, historical copper lives provide no guidance in estimating fiber lives.

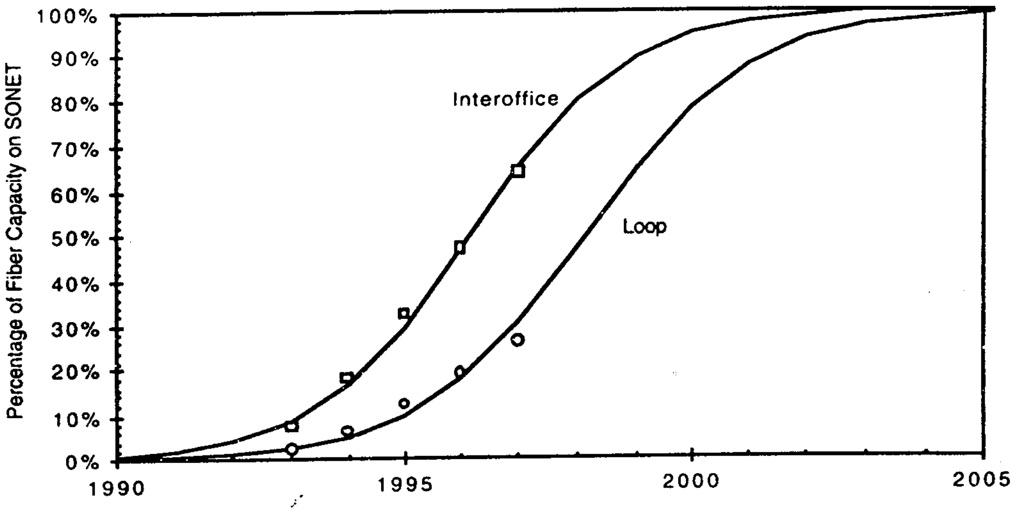
[16] C. M. Lemrow, Corning Glass Works, "How Much Stress Can Fiber Take?," *Telephony* (May 23, 1988):82. Also, Bellcore Technical Advisory Committee, *Generic Requirements for Optical Fiber and Optical Fiber Cable*, Issue 8 (TA-NWT-000020, December 1991), p. 2.

[17] Competitive risk was addressed by Moody's Investors Service (see *Telecommunications Reports* [December 6, 1993]:5) with its warning: "In addition, it says the trend toward telephone companies entering each other's local exchange markets through alliances with cable TV operators and the prospect of new wireless services have increased the competitive risk at the local loop level 'significantly.' Telco's debt ratings 'are likely to be downgraded as a result.' " The same risk to the telco's debt is faced by the telco's assets.

3.7 years.[18],[19] For existing digital circuit equipment, this ARL implies a projection life of eight to nine years for a typical company.

Exhibit 9

Adoption of SONET Equipment



Source: Technology Futures, Inc.

Lives for Analog Circuit Equipment

The analog circuit account includes analog carrier equipment and various other equipment for use in an analog environment, notably Metallic Facility Termination (MFT) equipment used for line treatment and conditioning on subscriber private-line loops and Switched Maintenance Access System (SMAS) test equipment used to test individual analog circuits.

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[18] This is a conservative estimate because, in addition to SONET, there are other drivers that will cause particular types of digital circuit equipment to be retired before 2000. First, D-channel banks have been and will continue to be replaced by Digital Crossconnect Systems, as well as by direct interfaces to digital switches. Second, T-1 terminal equipment and repeaters are retired when fiber optics systems are deployed. Third, central office DLC terminals are being replaced by direct DLC interfaces into switches, which also eliminate the need for line cards on the switch.

[19] See Table 3.4 in Attachment 3 for ARL computations.

Analog carrier equipment has no economic value, but, in a few places, it has yet to be officially retired. It simply has no place in a digital network. The appropriate remaining lives of this equipment should be zero or at least very, very low.

The other analog circuit categories are also basically obsolete. Conditioned lines are usually used for private lines that carry data traffic via modems, at faster data rates than can be handled on standard lines. In many cases, digital private lines are replacing conditioned analog lines for these applications; in others, improved modems allow the same data rates over unconditioned lines. SMAS test capability is being replaced by digital circuit equipment such as Digital Access and Cross-connect Systems (DACS).

To keep things simple, we estimate the life of the entire analog circuit account by tying it to the demise of the analog central office environment, in particular the demise of analog switching for the industry. Although some companies have already replaced their analog switching, the industry ARL should be a good surrogate for the end of the analog environment. This is conservative since much of the account, especially analog carrier, will be gone before analog switching. Our forecast for analog switching, shown in Exhibit 10, yields an ARL of 2.8 years as of 1/1/95. Thus, we recommend this as the maximum reasonable life for analog circuit equipment. For a typical range of companies, this ARL corresponds to a projection life of six to nine years.

Lives for Analog Switching

Exhibit 10 shows the percentage of access lines on the major switch technology types. At year-end 1993, ASPC switching served 31% of access lines. We expect this figure to fall to 5% by 1998 and 1% by 2001. The forecasts were derived using a multiple substitution analysis of historical and planning data.[20] The forecast implies an ARL of 2.8 years for analog switching.[21]

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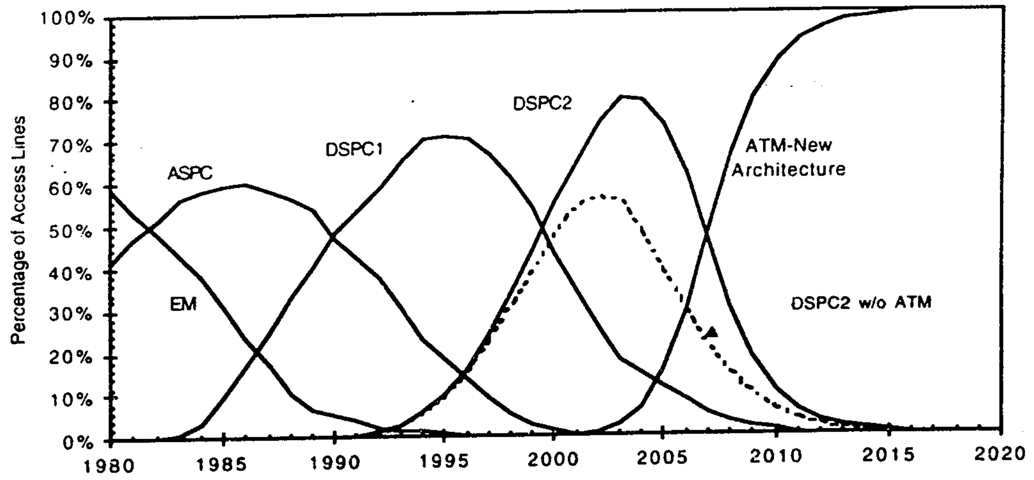
[20] The historical data through 1989 are from TFI files. The historical data for 1990-1993 are from ARMIS reports filed with the FCC, and the planning data for 1994-1995 are the weighted average from eight LECs (representing over 100 million working channels in 1993) that provided us with planning data.

[21] See Table 3.5 in Attachment 3 for ARL computations.

Exhibit 10

Switching Technology Shares



Source: Technology Futures, Inc.

Lives for Digital Switching

There are two factors to consider in computing digital switching lives. First, digital switches use a modular architecture that allows individual components of the switch to be upgraded independently to increase capacity, improve performance, or add new features and capabilities without having to completely replace the switch. This creates interim retirements of the components that are upgraded. At the end of the life of a switch entity, most of its components will likely have been replaced at least once. Second, today's switch architectures, flexible as they are, will ultimately be replaced by a new switching architecture based on ATM.

Our approach to estimating digital switching lives is to concentrate on interim retirements. We divide the switch into its major components and estimate the life for each component using technology forecasting. Then, a composite life is estimated by weighting the component lives by their percentage of switch investment. Digital switching, being relatively new, has experienced relatively few modular changeouts so far. However, there is evidence that interim retirement rates are increasing, and our forecasts indicate that they will increase dramatically in the future.

The major functional components of a digital switch are the following:

- *Central Processor/Memory*—This is basically computer equipment that provides the "brains" of the switch.
- *Switching Fabric*—This provides the very basic function of a switch: making the connections between incoming and outgoing communications channels.
- *Trunk Interfaces*—These connect the switch to interoffice transmission facilities leading to distant switches.
- *DLC Line Interfaces*—These connect the switch to DLC facilities in the loop plant.
- *Baseband Line Interfaces*[22]—These connect the switch to baseband copper loops dedicated to individual customers. (Traditionally, these provide analog POTS service, but this category includes equipment providing baseband digital services such as narrowband ISDN as well.)
- *Shell*—This is the common equipment, such as some cabling and power equipment, that is not modular and will last the life of the switch entity.[23]

Exhibit 11 illustrates how these components make up a digital switch.

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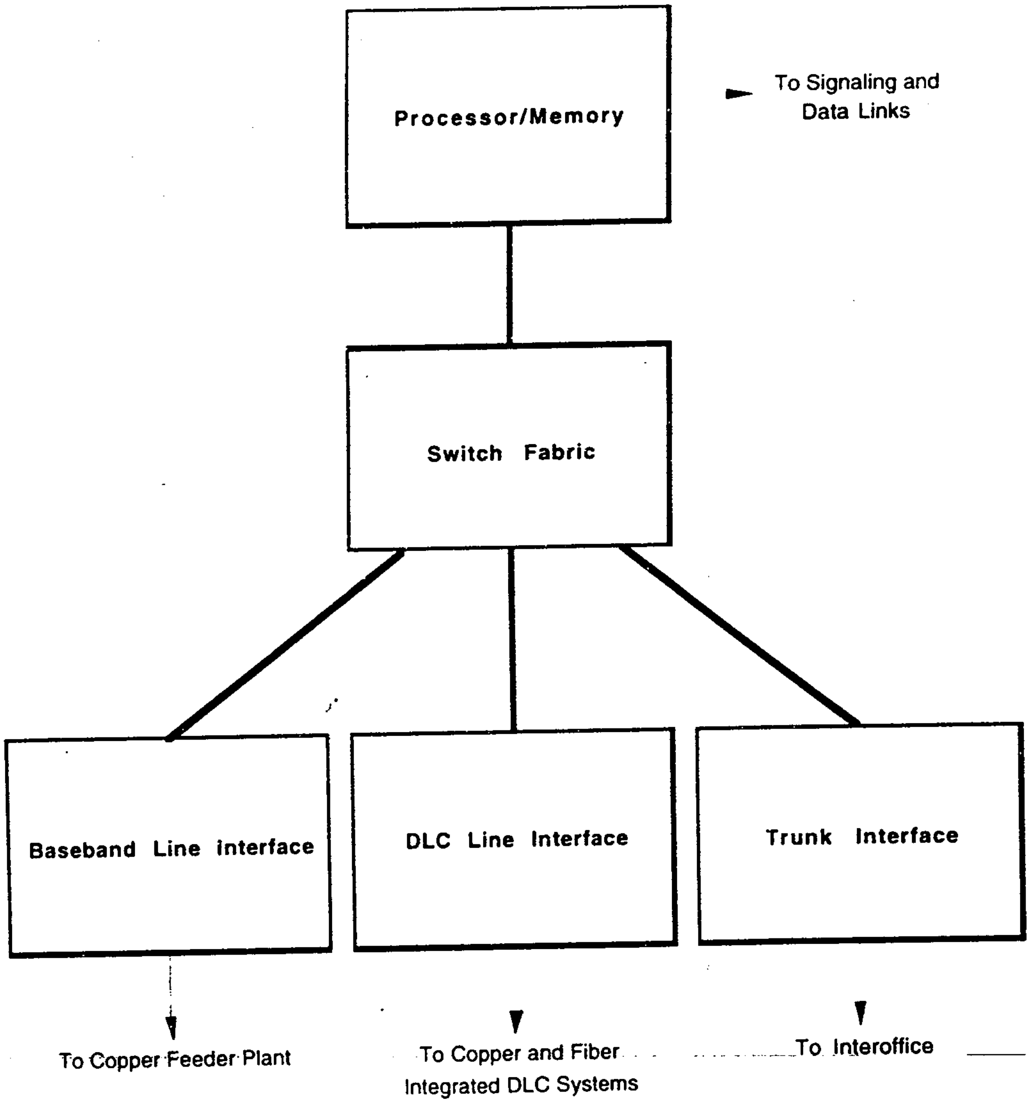
[22] Technically, baseband refers to signals that are not multiplexed or modulated, where the conductors carry the signal for only a single channel. Here, we extend the definition slightly to include services such as narrowband ISDN which involves several channels from the same customer on a single copper pair.

[23] In some cases, it may include the physical housing of switch components, but often these are replaced along with the components.

Exhibit 11

Generic Switching Architecture



Source: Technology Futures, Inc.

As noted, the modularity of the digital switch creates interim retirements of the components that are upgraded. Our analysis, summarized in Exhibit 12, yields a composite ARL of 6.3 years as of 1/1/95. For *existing* equipment, this corresponds to a projection life of nine to 11 years, depending on the average age of existing equipment.

Exhibit 12

Digital Switching—Modular Retirement Analysis

Component	% of Investment	Key Drivers	ARL (years)	Composite Contribution (years)
Processor/Memory	29%	Life cycle	5.0	1.47
Switching Fabric	5%	Life cycle & ATM	8.0	0.43
Trunk Interface	12%	IO SONET + 2 yrs	4.5	0.54
DLC Line Interface	4%	Feeder SONET + 2 yrs	6.3	0.25
Baseband Line Interface	40%	DLC, FITL, & Dig Services	6.3	2.52
Shell	8%	ATM Architecture	13.3	1.06
Composite	100%	Composite ARL = (as of 1/1/95)		6.3

Source: Technology Futures, Inc.

The investment proportions shown in the exhibit are a composite of studies by several LECs. Note that the processor/memory and line interfaces represent, by far, the greatest portion of switch investment, comprising 73% of the investment in the switch, and that the shell represents less than 10%.

The component lives shown in Exhibit 12 were estimated by a combination of methods. The processor/memory life was based on a 1992 analysis of first-generation purchases and retirements for Northern Telecom switches.[24] The switch fabric life was based on our forecast for the integration of ATM into existing switches, as well as near-term changeouts. The trunk interface and DLC line interface lives were based on the SONET adoption forecasts presented earlier, with a two-year lag added to account for the delayed impact on switching. The life for the largest component, analog line interfaces, was based on forecasts of the adoption of integrated DLC and FITL, as well as the impact of new digital services, including narrowband ISDN on non-DLC access lines.

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[24] L. K. Vanston, B. R. Kravitz, and R. C. Lenz, *Average Projection Lives of Digital Switching and Circuit Equipment* (Austin, TX: Technology Futures, Inc., 1992). Prepared for the United States Telephone Association (USTA).

The shell, which comprises less than 10% of the investment in a switch, is the part that is not modular and will last the life of the switch entity. The shell will be retired when ATM switches dominate the public network. Exhibit 13 shows our forecast for the percentage of access lines served by ATM switching, along with the ATM implementation method.[25] The first ATM switches in the public network are separate switches that are overlaid on the existing network. Next will come ATM as a separate switching fabric in existing switch architectures. Neither of these developments will have much impact on existing narrowband switch lives. Once certain conditions are met, voice traffic will begin to migrate to ATM. First, an ATM fabric will become the primary fabric in existing digital switches, replacing the narrowband fabric.[26] Eventually, however the entire switch entity will likely be retired. After all, today's digital switch architectures were not optimized for ATM, and they will eventually run out of steam like electromechanical and analog electronic switches have.[27] The percentage of access lines served by ATM as a new architecture is used to estimate the life of the shell. The replacement by a new architecture is not forecast to occur until after 2000, and its exact timing is subject to significant uncertainty. However, this uncertainty is not problematic in estimating digital switching lives, because the shell's percentage of the switch investment is so small.

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[25] This forecast assumes that ATM's initial application is limited to data services and ATM does not reach 1% of access lines until the end of 1996, but that, thereafter, ATM is adopted at the same average pace as digital switching was. The implementation estimates were derived from the results of a 1993 survey of network planners at nine LECs.

[26] ATM switches are incredibly fast, have tremendous capacity, and have a low cost per unit of bandwidth. As the cost gets even lower and certain other requirements are met, it will become more economical to switch voice on ATM than on traditional switching fabrics.

[27] There are several alternative scenarios for how ATM switching may be adopted. For example, narrowband services may migrate directly to new ATM switches, rather than first being implemented as primary fabrics on existing switches. Alternatively, it is possible that today's digital architectures, upgraded to ATM could prove more resilient than expected, postponing the adoption of a new architecture. Also, it is possible that narrowband services could stay on narrowband fabrics longer than expected. Finally, LECs might delay upgrades to existing digital switches in anticipation of ATM. As discussed in *Transforming the Local Exchange Network*, none of these scenarios is likely to significantly affect our estimate of composite lives for digital switching.

Exhibit 13

ATM Switching—Percentage of Access Lines

Year	Digital Switching (All Types)	FITL	ATM Switching
1993	68.0%	0.2%	0.0%
1994	76.1%	0.4%	0.1%
1995	80.6%	0.8%	0.6%
1996	86.1%	1.5%	1.0%
1997	90.2%	2.8%	1.7%
1998	94.8%	5.2%	2.7%
1999	97.3%	9.1%	4.5%
2000	98.6%	15.3%	7.2%
2001	99.3%	23.6%	11.5%
2002	99.6%	33.1%	17.8%
2003	99.8%	42.4%	26.5%
2004	99.9%	51.0%	37.5%
2005	99.9%	59.0%	50.0%
2006	100.0%	67.1%	62.5%
2007	100.0%	75.0%	73.5%
2008	100.0%	82.2%	82.2%
2009	100.0%	88.2%	88.5%
2010	100.0%	92.5%	92.8%
2011	100.0%	95.4%	95.5%
2012	100.0%	97.3%	97.3%
2013	100.0%	98.4%	98.3%
2014	100.0%	99.1%	99.0%
2015	100.0%	99.5%	99.4%

Source: Technology Futures, Inc.

Summary

The forecasts imply rapid obsolescence of the existing local telecommunications infrastructure and accelerated adoption of new technology. These changes, driven by technology advance, competition, and new services, are occurring across all major categories of network equipment. The recommended lives implied by our forecasts are summarized in the table below. These are industry averages, although they should generally apply to individual companies with modest variation. These lives are significantly shorter than those used in regulatory accounting. They reflect the realities of technological change and the need to provide advanced communications services. They do not, however, fully reflect the impact of competition on the economic life of equipment and, therefore, may still be too long.

Exhibit 14

TFI Equipment Life Recommendations

Technology	Recommended Industry Average Remaining Life (1/1/95)	Corresponding Projection Life[*]
Outside Plant		
Interoffice Cable, Metallic	2.9	
Feeder Cable, Metallic	7.0 to 7.8	
Distribution Cable, Metallic	7.5 to 10.2[**]	
Metallic Cable, Averaged	7.0 to 8.7[**]	14 to 16
Cable, Non-Metallic, All Types	-	15 to 20[‡]
Circuit Equipment		
Analog	2.8	6 to 9
Digital	3.7	8 to 9
Switching Equipment		
Analog	2.8	-
Digital	6.3	9 to 11[§]

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[*] These are estimates for the industry average; some companies may have lower or higher projection lives. Note: The projection life is for the installed base not newly-installed equipment, and depends on the particular distribution of plant a company has.

[**] Ignoring competition for voice services.

[‡] The 15-year projection life reflects risk due to competition.

[§] This is a reasonable range of projection lives for existing equipment that corresponds to the recommended industry ARL of 6.3 years. Companies with a shorter ARL may have a shorter projection life.

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Attachment 1

Substitution Analysis and the Fisher-Pry Model

Substitution analysis examines patterns of technology substitution—a pattern which is remarkably consistent from one substitution to another. The adoption of a new technology starts slowly. As the new technology improves, it becomes generally recognized as superior. The old technology, because of inherent limitations, experiences falling market share.

If the percentage of the total market captured by a new technology is plotted over time, an S-shaped curve results. Experience shows that a particular set of models, namely the Fisher-Pry model and its extensions, is most useful for forecasting. The model was first described by Fisher and Pry in 1971.[1] It has been shown to be appropriate for substitutions in both telecommunications and other industries. More than 200 substitutions, in industries ranging from chemicals to

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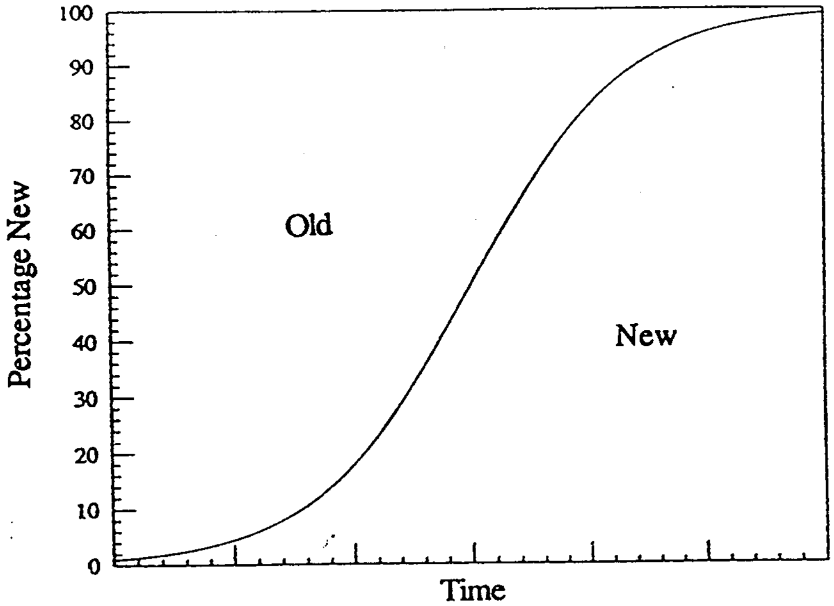
[1] J. C. Fisher and R. H. Pry, "A Simple Substitution Model of Technological Change," *Technological Forecasting and Social Change* 3 (1971), pp. 75-88.

aviation, have been identified that fit the Fisher-Pry pattern.[2] The S-shaped curve defined by the Fisher-Pry model is shown in Exhibit 1.1.

Exhibit 1.1

The Fisher-Pry Model



Source: Technology Futures, Inc.

Mathematically, the model can be written:

$$y(t) = 1 / (1 + e^{-b(t-a)})$$

where **y(t)** is the fraction of the new technology at time **t**. The parameter **a** is the time the new technology reaches 50% of the total universe of the old and new technology. The parameter **b** measures how fast the substitution proceeds. Another commonly-used measure for the rate of substitution is the Fisher-Pry annual substitution rate, defined as $\mathbf{r = (e^{b}-1) \times 100\%}$.

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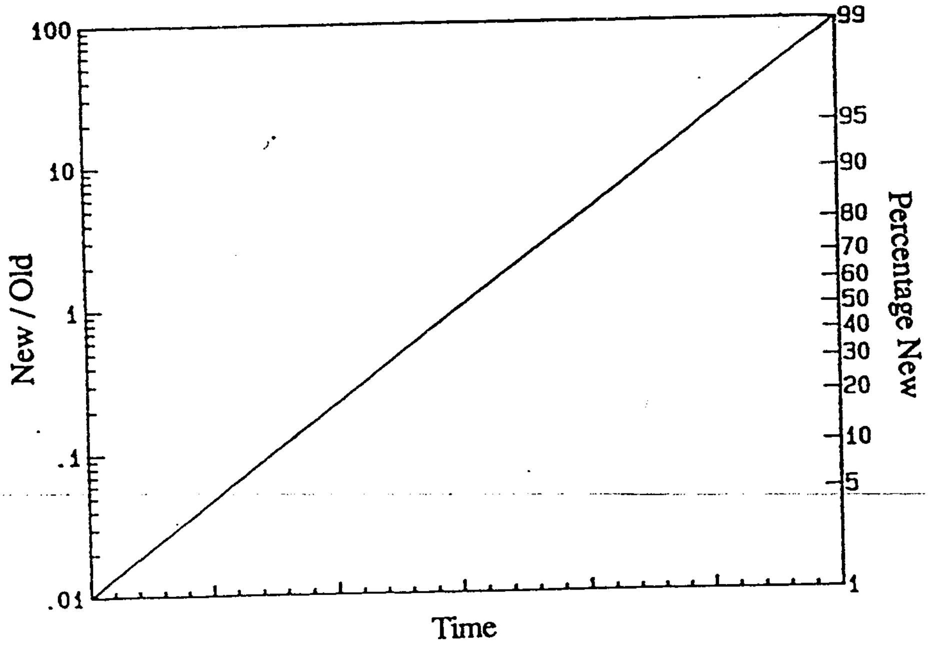
[2] R. C. Lenz and L. K. Vanston, *Comparisons of Technology Substitutions in Telecommunications and Other Industries* (Austin, TX: Technology Futures, Inc., 1986).

The shape of the curve is remarkably constant from substitution to substitution. However, the time period over which the substitution takes place varies greatly from one substitution to another. In electronics, complete substitution may occur in less than 10 years, while, in the past, complete substitution may have taken over 20 years for some telecommunications substitutions. Today, telecommunications substitutions are becoming somewhat more like those in electronics. The time period is related to the substitution rate for a particular substitution.

The ratio of the new technology to the old technology is called the Fisher-Pry ratio. Against time, the Fisher-Pry ratio plots as a straight line on a semilogarithmic graph, as shown in Exhibit 1.2.

Exhibit 1.2

Linearized Fisher-Pry Model



Source: Technology Futures, Inc.

The right-hand scale on the graph shows the market penetration of the new technology. The semilogarithmic graph is commonly used when analyzing data because it is easier to visualize than an S-shaped curve. The S-shaped curve is more often used for the presentation of results because it is easier to explain and interpret.

Forecasting with Fisher-Pry

With the Fisher-Pry model, the future course of a partially-complete substitution can be forecast. Using linear or non-linear regression analysis, historical data can be used to obtain estimates for the parameters **a** and **b**. These estimates can then be entered into the Fisher-Pry equation to obtain projections for future years.

In some cases, it is necessary to forecast the adoption of a new technology before it has begun to penetrate the market. Lacking historical data, forecasters can turn to analogies. For example, if similar historical substitutions occurred at substitution rates from 50% to 100%, one can posit that the new substitution may occur at the rate of about 75% (or 50%, to be conservative). Also, expert opinion and other forecasting techniques can be used to aid in estimating the appropriate rate.

Extensions of Fisher-Pry

In practice, not all technology substitutions exactly follow the Fisher-Pry model. For example, in some telecommunications substitutions, an early rapid rate of substitution has been observed to prevail up to the 10% level of substitution, followed thereafter by a somewhat slower rate. Beyond the 90% substitution point, the rate tends to increase again. Forecasts can be adjusted to account for this deviation by referring to historical substitutions as analogies.[3] In the case of multiple substitution (described below) and in other situations, such as capital constrained substitution, a more rigorous approach can be taken.

Multiple substitution occurs when the substitution of one technology for another is in progress and a third technology enters the market. For example, digital switching was introduced before analog electronic switches had completely replaced electromechanical switches, so both analog and digital switches were substituting for electromechanical. Research over the past nine years has

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[3] For example, see Lenz and Vanston, *Comparisons*.

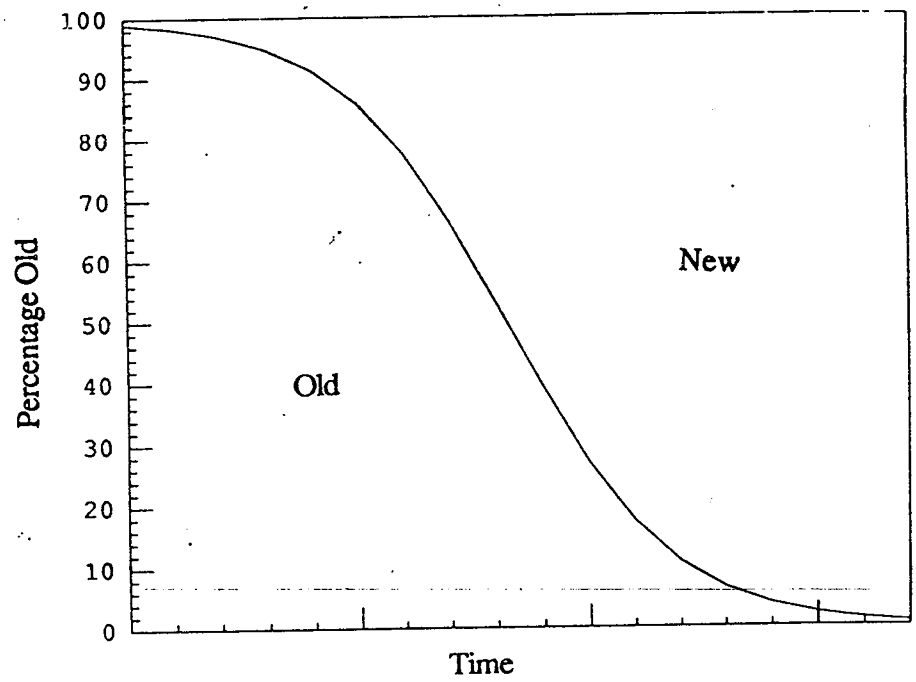
provided an improved understanding of multiple substitution, and practical techniques have been developed for dealing with it.[4]

Projecting the Market Share of the Old Technology

The market remaining for the old technology is derived by simply subtracting from 100% the percentage of new technology determined by the Fisher-Pry model. As shown in Exhibit 1.3, this is the same as reversing the S-shaped curve.

Exhibit 1.3

Market Share of the Old Technology



Source: Technology Futures, Inc.

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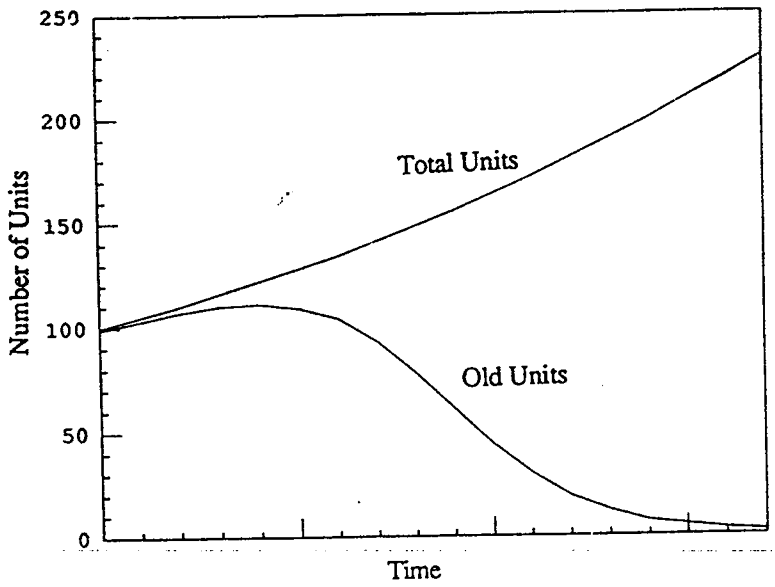
[4] See John W. Keith, *Applications of the Fisher-Pry Model to Non-Homogeneous Technological Populations*, NYNEX Service Company (1987) included as Appendix H in L. K. Vanston and R. C. Lenz, *Technological Substitution in Transmission Facilities for Local Telecommunications* (Austin, TX: Technology Futures, Inc., 1988). Also, see L. K. Vanston and R. C. Lenz, *Technological Substitution in Switching Equipment for Local Telecommunications* (Austin, TX: Technology Futures, Inc., 1988), pp. 11-16.

Projecting the Number of Units

The Fisher-Pry model predicts the *percentage* of new and old technology. To calculate the ***number*** of units of each, an independent forecast of the total market must be made. Multiplying the total by the percentages yields the number of units of the old and new technology. Exhibit 1.4 illustrates how growth (in this case, a 5% per year growth rate) affects the number of units of the old technology. Although the old technology is losing market share, it can continue to grow for several years after the introduction of the new technology. The faster the growth relative to the substitution rate, the larger the effect.

Exhibit 1.4

Projecting the Number of Units



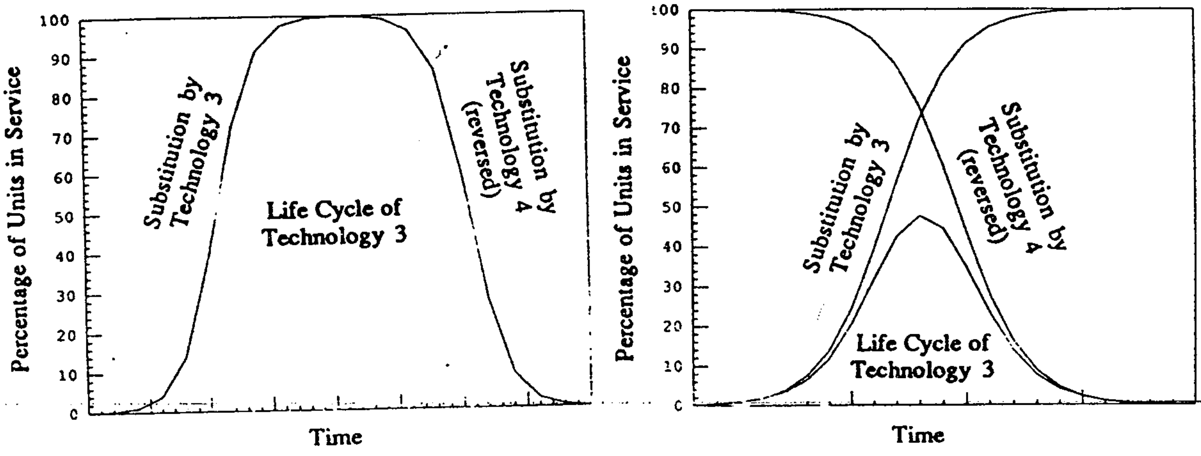
Source: Technology Futures, Inc.

Relationship to Product Life Cycles

The product life cycle shows the units of a technology in service over time. Fisher-Pry can be used to forecast the product life cycle on a percentage basis, which can then be used to state the forecast in terms of the number of units. Basically, when a technology is new, its S-shaped substitution curve forms the up side of the product life cycle. When a newer technology comes along, the reverse of its S-shaped substitution curve forms the down side of the product life cycle for the earlier technology. This process is illustrated in Exhibit 1.5a. This simple explanation applies only when the substitutions do not overlap, i.e., the first substitution is complete before the second begins. This situation is now rare in the electronics, computer, and telephone industries, where new technologies come on the heels of one another. For overlapping substitutions, the connection between the S-shaped substitution curves and the life cycles is more complicated, as indicated in Exhibit 1.5b.[5]

Exhibit 1.5

Fisher-Pry and Life Cycles



Source: Technology Futures, Inc.

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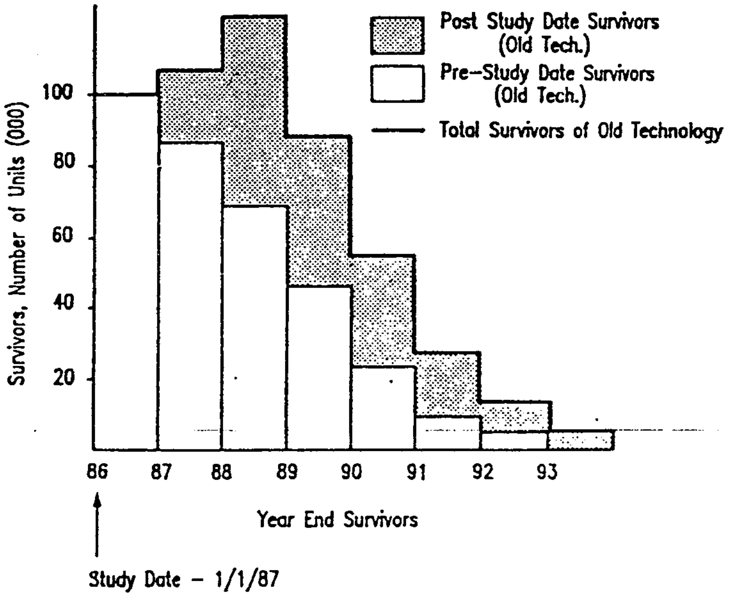
[5] A more detailed explanation is given in Appendix A of L. K. Vanston, B. R. Kravitz, and R. C. Lenz. *Average Projection Lives of Digital Switching and Circuit Equipment* (Austin, TX: Technology Futures, Inc., 1992).

Forecasting Depreciation Lives

Fisher-Pry substitution analysis can be used to forecast end dates for an old technology, which can then be incorporated into a standard depreciation analysis. Fisher-Pry can also be used to help derive the survivor curve from which the average remaining life (ARL) of the old technology can be calculated. This process involves several steps. First, the forecast must be stated in terms of the units of old technology, as discussed above. This curve includes all survivors of the old technology, while the survivor curve applies only to equipment in place as of the study date. Thus, to obtain the survivor curve, we must subtract the additions of the old technology that are added after the study date, as well as equipment retired due to normal mortality as illustrated in Exhibit 1.6.[5]

Exhibit 1.6

Computing the Survivor Curve



Source: Technology Futures, Inc.

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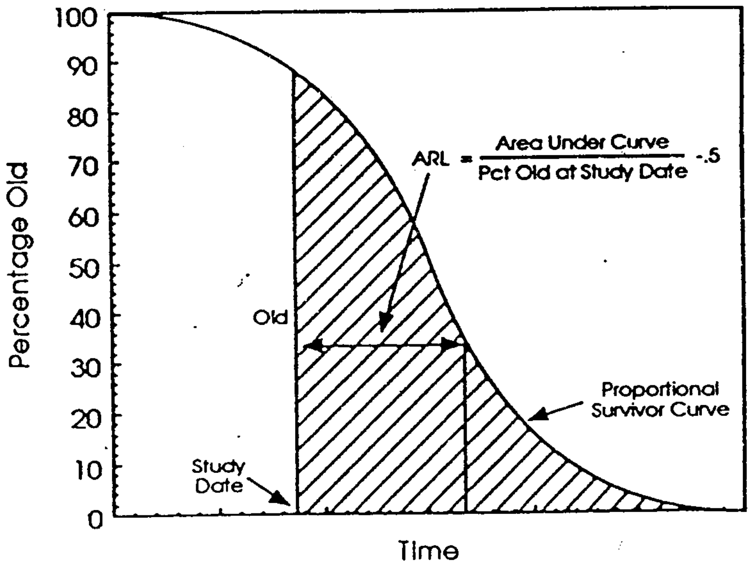
[5] For more details, see TechOver™ manual (Austin, TX: Technology Futures, Inc., 1987), pp. 8.1-8.10.

For general studies, a reasonable estimate of ARL can be obtained by using the proportional curve directly, as illustrated in Exhibit 1.7. Neglecting growth may cause the ARL to be underestimated by about a year, while neglecting retirements due to normal retirements can cause the ARL to be overestimated by about as much. These factors tend to balance each other and, thus, forecasters get a good estimate unless the growth rate is extremely high or normal retirements are especially low.

Exhibit 1.7

Estimating the Average Remaining Life from the Old Technology Market Share



Source: Technology Futures, Inc.

Company Forecasts

Substitution analysis can be applied to both an individual company's data or to industry data. Naturally, industry data, spread over a larger population, tends to produce smoother curves. Also, individual companies may lag the industry substitution, but toward the end of the substitution, they tend to increase their rate of substitution and catch up with the industry. This has the effect of causing the entire industry to have essentially the same end-date and keeps the industry on the Fisher-Pry curve.[7] This observation is not surprising, since a company cannot stay competitive (or in business) if it fails to keep up with its competitors in the adoption of more efficient technology.

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[7] R. C. Lenz and L. K. Vanston, *The Effects of Various Levels of Aggregation in Technology Substitutions* (Austin, TX: Technology Futures, Inc., 1987).

Attachment 2

List of TFI Publications

Technology's Impact on Lives of Telecommunications Equipment at New York Telephone, Technology Futures, Inc. (1985).

Comparisons of Technology Substitutions in Telecommunications and Other Industries, Ralph C. Lenz and Lawrence K. Vanston (1986).

The Effects of Various Levels of Aggregation in Technology Substitutions, Ralph C. Lenz and Lawrence K. Vanston (1987).

Technological Substitution in Transmission Facilities for Local Telecommunications, Lawrence K. Vanston and Ralph C. Lenz (1988).

Technological Substitution in Switching Equipment for Local Telecommunications, Lawrence K. Vanston and Ralph C. Lenz (1989).

Technological Substitution in Circuit Equipment for Local Telecommunications, Lawrence K. Vanston (1989).

Future Technology in the Local Telecommunications Network, An Expert Opinion Survey, Lawrence K. Vanston and William J. Kennedy (1989).

"How Fast is New Technology Coming?" *Telephony*, Lawrence K. Vanston, Ralph C. Lenz, and Richard Wolff (September 18, 1989).

A Facsimile of the Future: Forecasts of Markets and Technologies, Lawrence K. Vanston, William J. Kennedy, and Samia El-Badry-Nance (1991).

Average Projection Lives of Digital Switching and Circuit Equipment, Lawrence K. Vanston, Bruce R. Kravitz, and Ralph C. Lenz (1992) for the United States Telephone Association (USTA).

Computer-Based Imaging and Telecommunications: Forecasts of Markets and Technologies, Lawrence K. Vanston, Samia El-Badry-Nance, William J. Kennedy, and Nancy E. Lux (1992).

Interactive Multimedia and Telecommunications: Forecasts of Markets and Technologies, Julia A. Marsh and Lawrence K. Vanston (1992).

Local Area Network Interconnection and Telecommunications, Bruce R. Kravitz and Lawrence K. Vanston (1992).

Video Communications, Lawrence K. Vanston, Julia A. Marsh, and Susan M. Hinton (1992).

Telecommunications for Television/Advanced Television, Lawrence K. Vanston, Julia A. Marsh, and Susan M. Hinton (1992).

New Telecommunications Services and the Public Telephone Network, Lawrence K. Vanston (1993).

Personal Communications: Perspectives, Forecasts, and Impacts, Ralph C. Lenz and Lawrence K. Vanston (1993).

Transforming the Local Exchange Network: Analyses and Forecasts of Technology Change, Lawrence K. Vanston (1994).

Wireless and Cable Voice Services: Forecasts and Competitive Impacts, Lawrence K. Vanston and Curt Rogers (1995).

Attachment 3

Tabular Data

Table 3.1

Interoffice Copper Cable Survivors

Year	% of Circuits on Copper Cable	% of 1994 Investment Surviving
1994	19.5%	100.0%
1995	13.6%	69.9%
1996	10.1%	51.8%
1997	7.2%	37.0%
1998	5.1%	26.2%
1999	3.6%	18.3%
2000	2.5%	12.8%
2001	1.7%	8.9%
2002	1.2%	6.1%
2003	0.8%	4.2%
2004	0.6%	2.9%
2005	0.4%	2.0%

Average Remaining Life (as of 1/1/95) = 2.9 years

Source: Technology Futures, Inc.

Table 3.2

Metallic Feeder Survivors

	Middle Scenario		Early Scenario	
Year	Metallic Pct of Feeder Access Lines	Pct of 1994 Investment Surviving	Metallic Pct of Feeder Access Lines	Pct of 1994 Investment Surviving
1994	83%	100%	83%	100%
1995	80%	96%	80%	96%
1996	75%	90%	75%	90%
1997	70%	84%	70%	84%
1998	64%	77%	64%	77%
1999	58%	70%	58%	70%
2000	51%	61%	51%	61%
2001	44%	53%	44%	53%
2002	37%	44%	37%	44%
2003	30%	36%	26%	31%
2004	24%	29%	15%	18%
2005	19%	23%	9%	10%
2006	15%	18%	5%	6%
2007	11%	14%	2%	3%
2008	9%	10%	1%	2%
2009	7%	8%	1%	1%
2010	5%	6%	0%	0%
2011	4%	4%	0%	0%
2012	3%	3%	0%	0%
2013	2%	2%	0%	0%
2014	1%	1%	0%	0%
2015	1%	1%	0%	0%
Average Remaining Life = (as of 1/1/95)		7.8 years		7.0 years

Source: Technology Futures, Inc.

Table 3.3

Distribution Copper Survivors

	Early Scenario			Late Scenario			Middle Scenario		
Year	Pct of Access Lines		Pct of Copper Lines Surviving	Pct of Access Lines		Pct of Copper Lines Surviving	Pct of Access Lines		Pct of Copper Lines Surviving
	Fiber	Copper		Fiber	Copper		Fiber	Copper	
1994	0.8%	99.2%	100.0%	0.1%	99.9%	100.0%	0.4%	99.6%	100.0%
1995	1.4%	98.6%	99.3%	0.1%	99.9%	99.9%	0.8%	99.2%	99.6%
1996	2.8%	97.2%	98.0%	0.2%	99.8%	99.8%	1.5%	98.5%	98.9%
1997	5.2%	94.8%	95.5%	0.4%	99.6%	99.7%	2.8%	97.2%	97.6%
1998	9.6%	90.4%	91.1%	0.7%	99.3%	99.3%	5.2%	94.8%	95.2%
1999	17.0%	83.0%	83.6%	1.3%	98.7%	98.8%	9.1%	90.9%	91.2%
2000	28.4%	71.6%	72.1%	2.2%	97.8%	97.9%	15.3%	84.7%	85.1%
2001	43.4%	56.6%	57.0%	3.8%	96.2%	96.3%	23.6%	76.4%	76.7%
2002	59.8%	40.2%	40.5%	6.4%	93.6%	93.7%	33.1%	66.9%	67.2%
2003	74.2%	25.8%	26.0%	10.7%	89.3%	89.4%	42.4%	57.6%	57.8%
2004	84.8%	15.2%	15.4%	17.2%	82.8%	82.9%	51.0%	49.0%	49.2%
2005	91.5%	8.5%	8.6%	26.6%	73.4%	73.5%	59.0%	41.0%	41.1%
2006	95.4%	4.6%	4.6%	38.7%	61.3%	61.3%	67.1%	32.9%	33.1%
2007	97.6%	2.4%	2.4%	52.4%	47.6%	47.7%	75.0%	25.0%	25.1%
2008	98.7%	1.3%	1.3%	65.7%	34.3%	34.3%	82.2%	17.8%	17.8%
2009	99.3%	0.7%	0.7%	77.0%	23.0%	23.1%	88.2%	11.8%	11.9%
2010	99.7%	0.3%	0.3%	85.3%	14.7%	14.7%	92.5%	7.5%	7.5%
2011			0.2%	91.0%	9.0%	9.0%	95.4%	4.6%	4.6%
2012			0.1%	94.6%	5.4%	5.4%	97.3%	2.7%	2.7%
2013			0.0%	96.9%	3.1%	3.1%	98.4%	1.6%	1.6%
2014			0.0%	98.2%	1.8%	1.8%	99.1%	0.9%	0.9%
2015			0.0%	98.9%	1.1%	1.1%	99.5%	0.5%	0.5%
2016			0.0%	99.4%	0.6%	0.6%			
	Avg Remaining Life (as of 1/1/95)		7.5	Avg Remaining Life (as of 1/1/95)		12.8	Avg Remaining Life (as of 1/1/95)		10.2

Source: Technology Futures, Inc.

Table 3.4

Non-SONET Circuit Equipment Survivors

Year	% of Equipment Not on SONET	% of 1994 Investment Surviving
1994	88%	100%
1995	79%	89%
1996	68%	76%
1997	53%	60%
1998	36%	41%
1999	23%	26%
2000	13%	15%
2001	7%	8%
2002	4%	4%
2003	2%	2%
2004	1%	1%
2005	0%	1%

Average Remaining Life (as of 1/1/95) = 3.7

Source: Technology Futures, Inc.

Table 3.5

Analog SPC Survivors

Year	% of Access Line on Analog SPC	% of 1994 Investment Surviving
1994	22.8%	100.0%
1995	18.7%	82.1%
1996	13.4%	58.9%
1997	9.5%	41.9%
1998	5.0%	22.1%
1999	2.6%	11.2%
2000	1.3%	5.6%
2001	0.6%	2.7%
2002	0.3%	1.3%
2003	0.1%	0.6%
2004	0.1%	0.3%
2005	0.0%	0.2%

Average Remaining Life (as of 1/1/95) = 2.8 years

Source: Technology Futures, Inc.

Table 3.6

Percentage Survivor Curves for Modular Categories of Digital Switching

1 Year	2 Processor/ Memory	3 Switching Fabric	4 Trunk Interface	5 DLC Line Interface	6 Baseband Line Interface	7 Shell
1993	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
1994	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
1995	90.0%	93.8%	100.0%	100.0%	96.3%	100.0%
1996	80.0%	87.5%	88.5%	96.0%	91.5%	100.0%
1997	70.0%	81.3%	73.0%	89.8%	84.0%	100.0%
1998	60.0%	75.0%	57.4%	82.7%	74.4%	100.0%
1999	50.0%	68.8%	39.3%	75.2%	65.1%	100.0%
2000	40.0%	62.5%	21.5%	53.8%	51.8%	99.9%
2001	30.0%	56.3%	11.3%	36.2%	39.1%	99.8%
2002	20.0%	50.0%	5.6%	21.8%	28.3%	99.2%
2003	10.0%	43.8%	2.7%	12.0%	19.6%	97.7%
2004	0.0%	37.5%	1.3%	6.3%	12.7%	93.6%
2005	0.0%	31.3%	0.6%	3.2%	7.9%	84.8%
2006	0.0%	25.0%	0.3%	1.6%	4.5%	69.9%
2007	0.0%	18.8%	0.1%	0.8%	2.5%	51.2%
2008	0.0%	12.5%	0.1%	0.4%	1.3%	33.6%
2009	0.0%	6.3%	0.0%	0.2%	0.7%	20.4%
2010	0.0%	0.0%	0.0%	0.1%	0.4%	11.9%
2011	0.0%	0.0%	0.0%	0.0%	0.2%	6.8%
2012	0.0%	0.0%	0.0%	0.0%	0.1%	3.8%
2013	0.0%	0.0%	0.0%	0.0%	0.1%	2.2%
2014	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%
2015	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Pct of Investment	29%	5%	12%	4%	40%	8%
ARL = (1/1/95)	5.0	8.0	4.5	6.3	6.3	13.3

Source: Technology Futures, Inc.