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100 YEARS ANNIVERSARY

Telecommunications Forecasting

Technology forecasting for telecommunications

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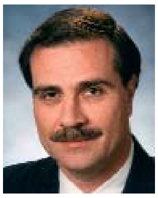
For the last twenty years we have been actively applying formal technology forecasting to the telecommunications industry. Over those years we have learned much and the personal computer and the Internet have made the job easier. However, the fundamentals of forecasting have remained the same, as has the basic challenge of balancing imagination and realism in thinking about the future.



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Technology forecasting in telecommunications has been a success story. This may seem like a bold statement given the recent debacle in the telecommunications industry, caused in part by some extremely poor forecasts. However, as we discuss later, the most notorious of these forecasts were produced by forecasting amateurs and consumed by uncritical investors and decision makers. Further, almost all of the problems experienced by the industry were forecastable and indeed forecasted.[1] The lesson is that good forecasting matters and that decision-makers need a rudimentary understanding of the principles of technology change and adoption.

The successes over the last twenty years are many and include good forecasts in the following areas: digital switching, digital transmission, fiber transport, SONET/SDH adoption, optical data rates, cellular adoption, digital cellular substitution, wireless/wireline competition, Internet demand, broadband access (e.g. DSL and cable modems), bandwidth demand, and DTV/HDTV, to name a few. Active forecasting areas where technology forecasting is crucial, but where it is still too early to gauge success, include VDSL, PONs, VoIP, IP PABXs, 3G wireless, wireless LANs, and the future increases in access bandwidth.

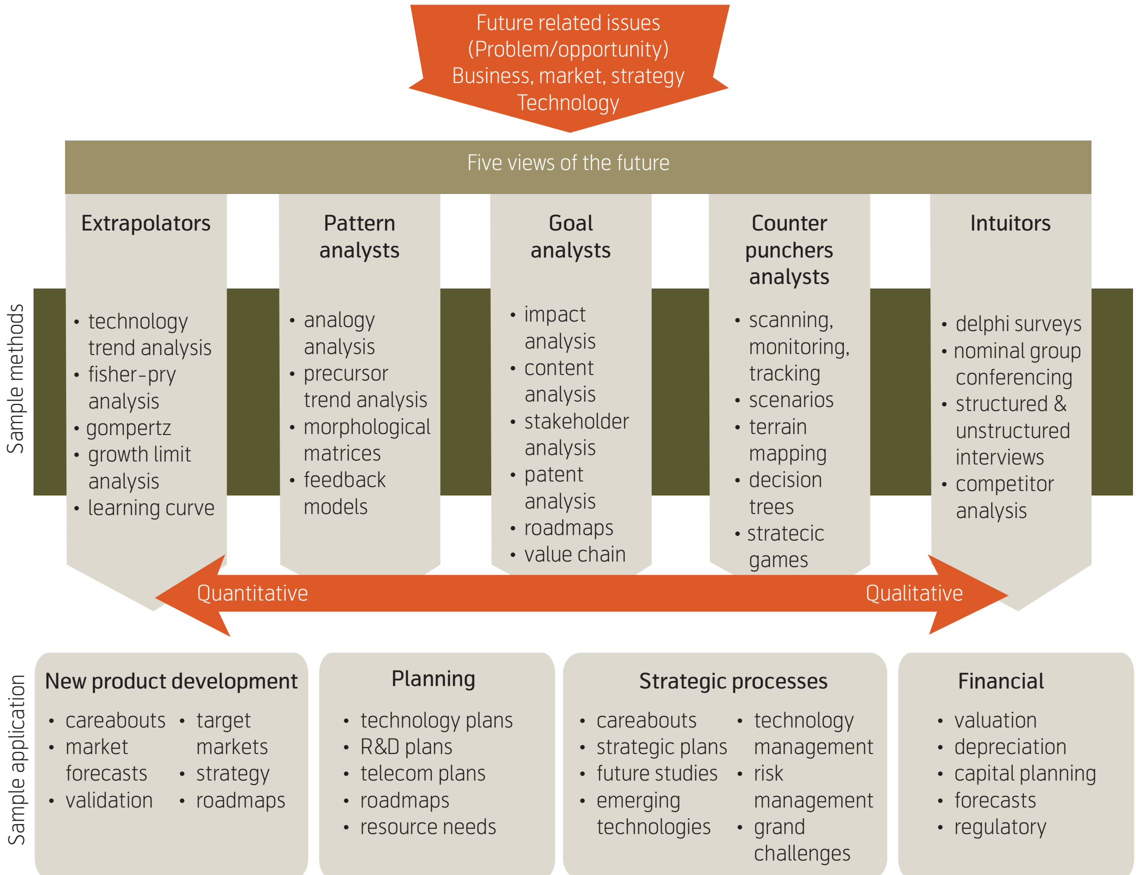

Figure 1 Five views of the future™ (Copyright © Technology Futures, Inc. 2004)

1) See for example [1]. Other examples are provided herein.

Technology forecasting toolkit

The technology forecasting tools that we have used the most in telecommunications are reasonably simple:

- Substitution and market adoption models, such as the Fisher-Pry and Gompertz curves;
- Technology performance and price/performance models, such as the Pearl curve and learning curves;
- Expert opinion methods, such as the Delphi method and structured interviews; and
- Structured thinking tools such as impact wheels and nominal groups.

It is beyond the scope of this paper to describe all of these tools, but they are worth learning because they can help the forecaster make good forecasts and help decision makers discriminate between good and bad ones [2].

A useful way of looking at technology forecasting, and classifying tools, is what we call the Five Views of the Future[TM] [3], which are represented by the extrapolator, the pattern analyst, the goal setter, the counter-puncher, and the intuitor as shown in Figure 1. An appreciation of all five views is most likely to produce good forecasts, good communication, and good decisions. The extrapolator and pattern analysis views, exemplified by substitution and adoption models, are the most visible in our published telecommunications forecasts, partially because of the need for quantitative results. However, we employ all five views and 90 % of the work is in the background, including almost always a qualitative analysis of drivers and constraints.

In this article, we review a number of past and current forecasts to give you an idea about our experience with technology forecasting and what we see for the future. These will be forecasts that TFI has produced, because we know them, they are public, and they are good examples, albeit mostly from the US.[2)] This is not to say we are the only producers of good forecasts. We are not being patronizing when we say that Telenor has for years been a leader in telecom forecasting. Also, in the last decade, the overall quality of commercial forecasting has improved tremendously.

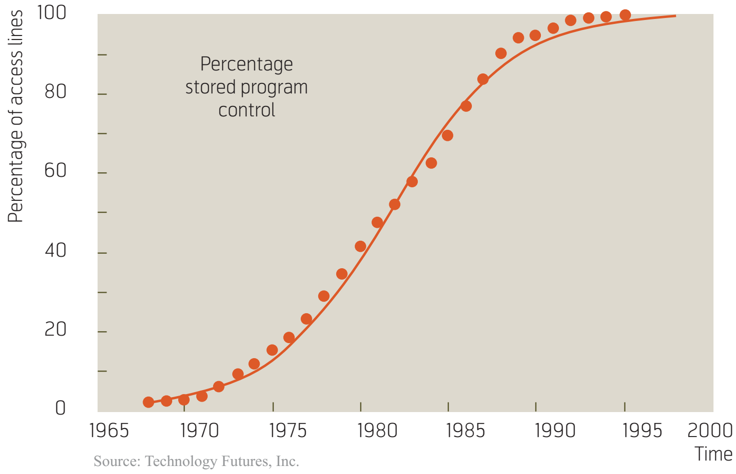

Figure 2 Percentage of telephone access lines served by SPC switching

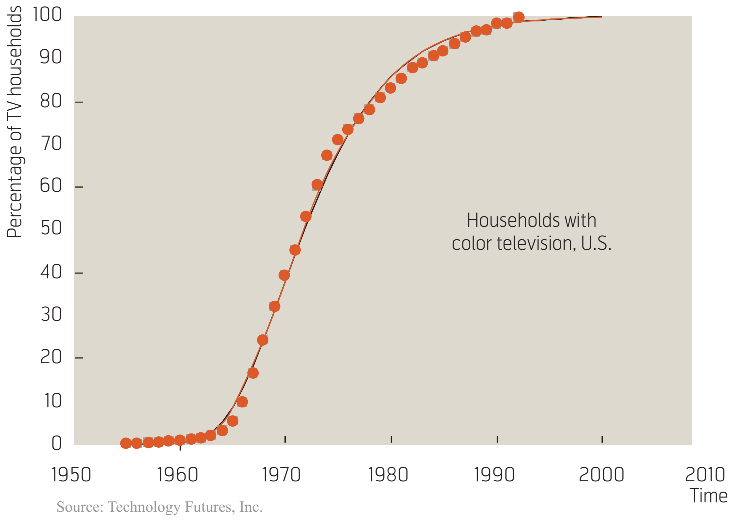

Figure 3 Percentage of US TV households with color televisions

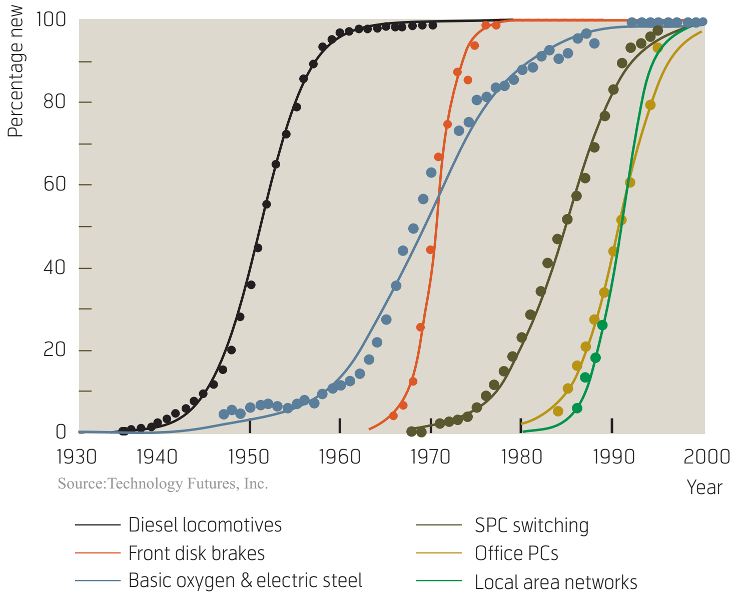

Figure 4 Fisher-Pry examples

2) *Many of the TFI forecasts presented here were sponsored by the Telecommunications Technology Forecasting Group (TTFG) comprised of major North American local telephone operators.*

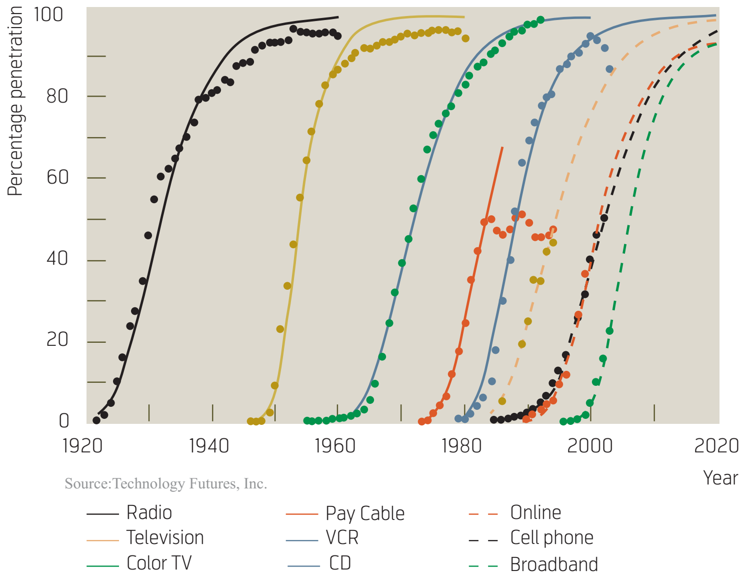

Figure 5 Gompertz examples (US)

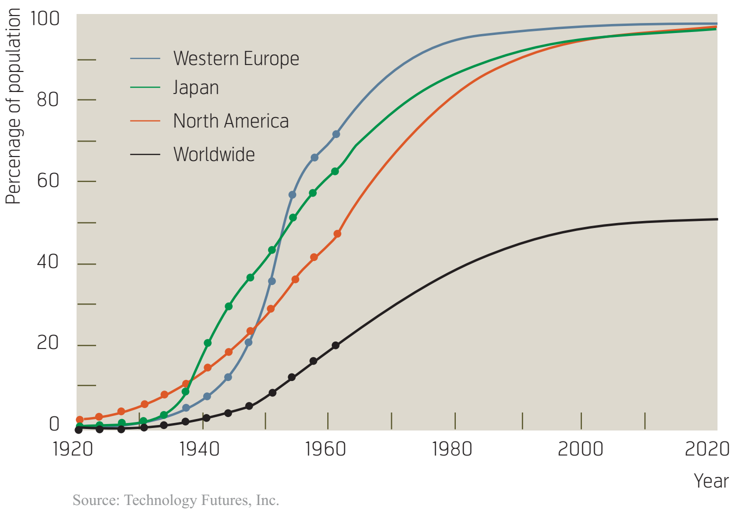

Figure 6 Adoption of cellular telephony

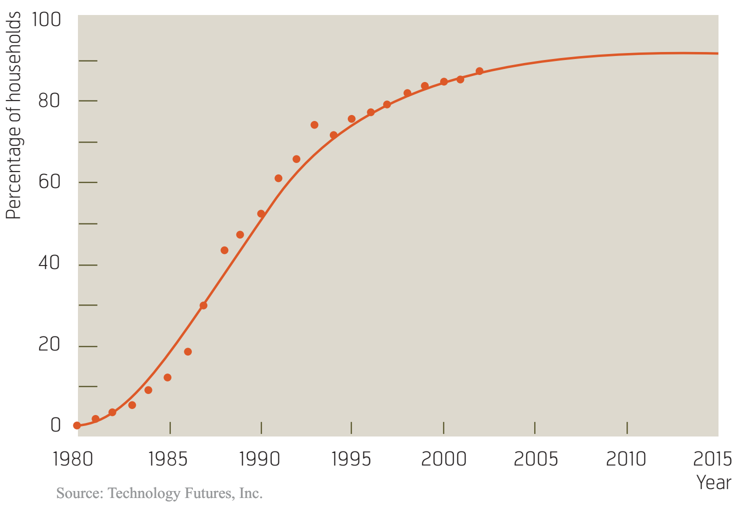

Figure 7 Television households in China

Patterns of technology adoption

The general pattern of technology adoption or substitution is an S-shaped curve when the percentage of the installed base captured by the new technology is plotted over time. For example, Figure 2 plots the adoption of stored program control (SPC) switching by US local telephone companies, measured as a percentage of access lines. Another example is shown in Figure 3, which shows the adoption of color television, measured by the percentage of US TV households.[3)]

The switching example uses a special case of the Logistic model (also used in forecasting) called the Fisher-Pry model [5], given by the formula:

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

The Fisher-Pry model is symmetrical about the 50 % penetration point, given by the **a** parameter. The **b** parameter governs how fast the adoption proceeds. It is a constant for any given Fisher-Pry adoption, but it varies among adoptions as apparent from Figure 4. The Fisher-Pry model is especially applicable to technology-driven adoptions where new technology displaces old technology because it is technically and economically superior.

The color TV example uses the Gompertz model, given by the formula:

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

The Gompertz model also forms an S-shaped curve, but it is asymmetric, with the adoption slowing down as it progresses. The Gompertz model is usually better for consumer adoptions. Again, the **b** parameter governs the rate of adoption which varies by technology as shown in Figure 5. The **a** parameter gives the inflection point which occurs at 37 % substitution.

The Fisher-Pry, Gompertz, and Logistic models can be applied at the country, regional, or worldwide levels, although for a given technology substitution or adoption, the **a** and **b** values, as well as the ultimate penetration level (not always 100 %), may vary. For example, Figures 6, 7, and 8 show the penetration of cellular telephony worldwide and for several regions, television penetration in China, and broadband penetration in Western Europe.

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3) *For a more detailed explanation of these models see [4].*

Using technology market adoption models for forecasting

With any of the models, we can forecast the future course of a partially complete substitution. Using regression methods, the appropriate model is fit to the historical data to obtain best-fit estimates of the parameters **a** and **b**. For example, Figure 9 shows the Gompertz model fitted to historical broadband penetration data assuming that ultimately 95 % of US households adopt broadband, a reasonable assumption given the drivers and the fact that broadband penetration in Korea already exceeds 75 % as shown in the figure.

Figure 10 shows an example using the Fisher-Pry model. In this case, we are forecasting the percentage of the installed base of PABX lines that use Internet Protocol switching, based on published historical data and a short-term forecast. (It is common to use planning data or short-term forecasts to slightly extend the available data for forecast of the complete substitution.)

Forecasting adoptions before and at introduction

We can apply these methods even in cases where the substitution has just begun, or has yet to begin, by using appropriate analogies, precursor trends, evaluation of the driving forces, or expert opinion. For example, Figure 11 shows TFI's 1999 broadband forecast when broadband penetration was about 1 %, too early for curve fitting. In that case we used the average **b** value of .21 for the consumer electronic adoptions. As it turned out, broadband has been one of the faster adoptions with a **b** value of .25.

Another example using an analogy comes from TFI's 1995 HDTV forecast shown in Figure 12. The forecasts assumed HDTV penetration in the US of 1 % at year end 2000. This was based on experience with other media technologies which indicated it usually takes three years to complete trials and another two years to go through the early commercialization stage and reach 1 % adoption. The forecast also assumed that once the adoption of HDTV began, it would be adopted at the same rate that color television was; in other words it would have the same Gompertz **b** value. The forecast we made in 1995 is not too different from our current HDTV forecast shown in Figure 13. Of course, now we have historical data and can use curve fitting as well as analogies.

A third example of using substitution analysis without historical data comes from TFI's 1989 forecast of SONET, North America's version of SDH. As shown in Figure 14, a simple analogy was used (fiber pene-

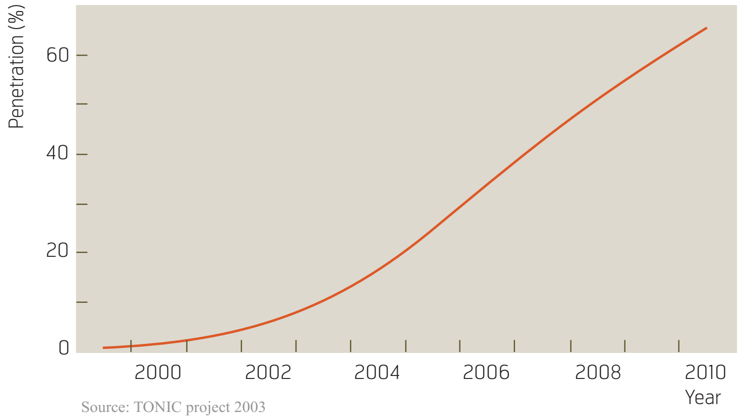

Figure 8 Broadband adoption, Western Europe [10]

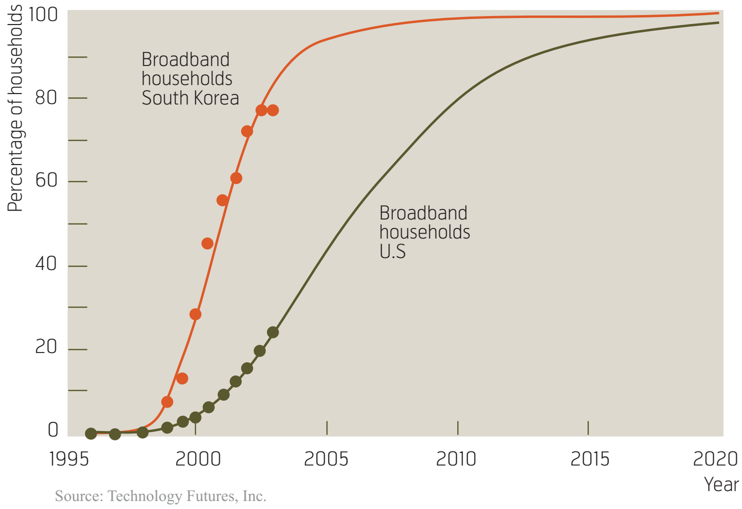

Figure 9 Broadband households (Data Sources: US Federal Communications Commission and Ministry of Information and Communication Republic of Korea)

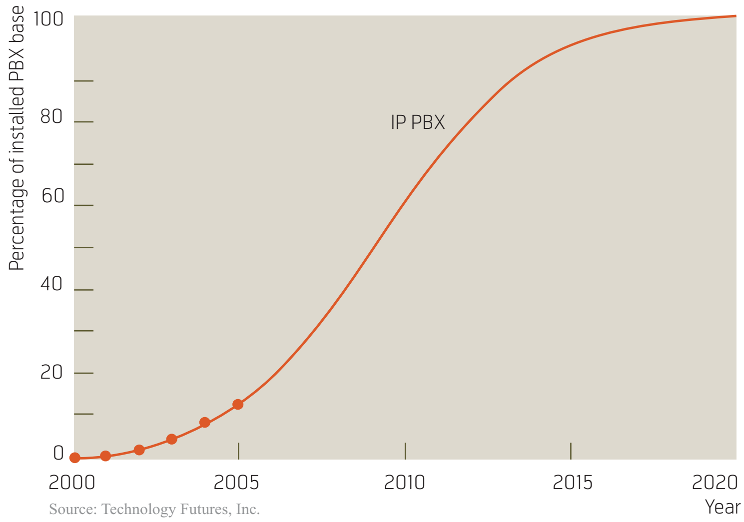

Figure 10 IP PABXs (US)

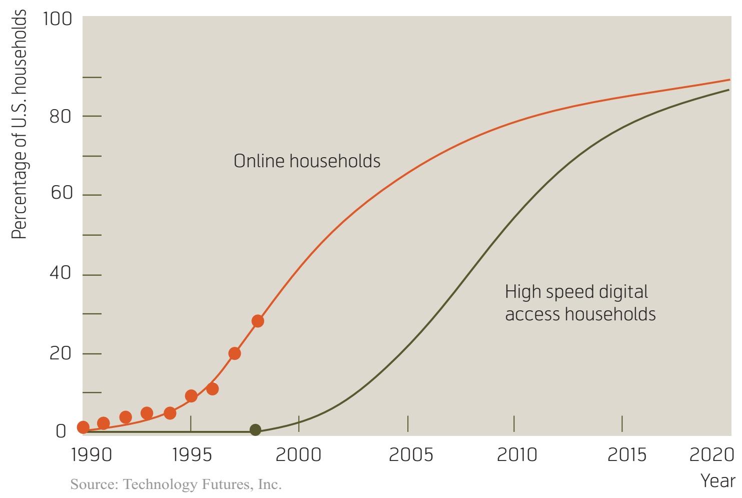

Figure 11 Forecasting by analogy – Broadband (1999 Forecast) [11]

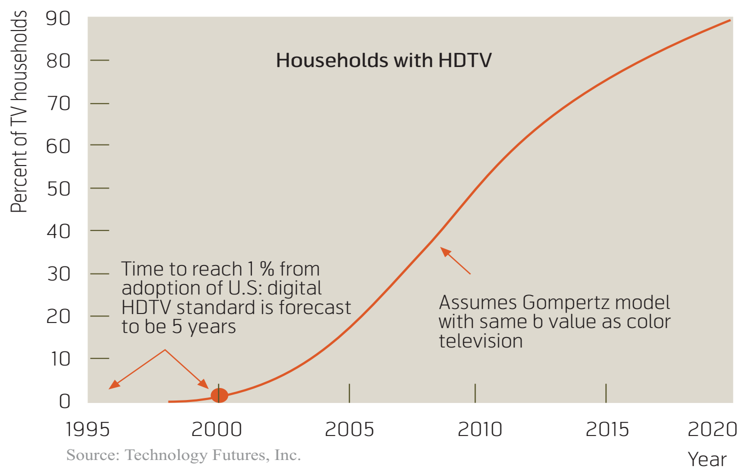

Figure 12 Forecasting by analogy – HDTV (1995 Forecast) [12] (This graphic appeared in Introduction to Technology Market Forecasting, 1996, p. 25)

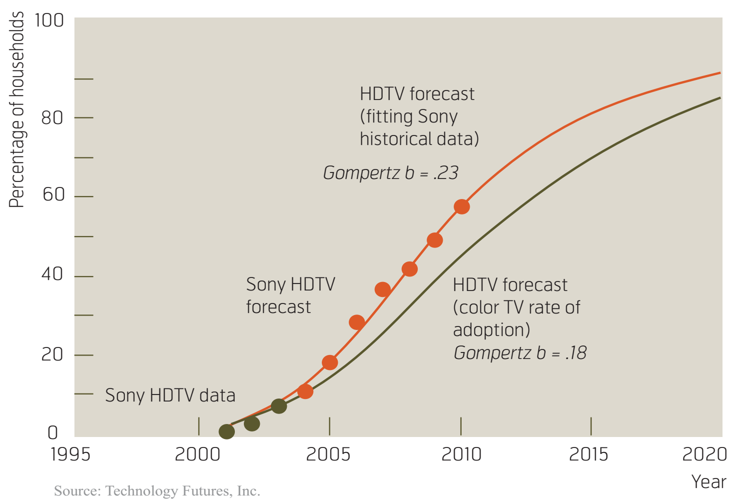

Figure 13 HDTV and DTV adoption (2004 Forecast)

tration of interoffice facilities), but this was supplemented by the results of an expert opinion survey which indicated the reasonableness of the forecast.

A final example of using substitution analysis without historical data employs trend analysis and linked substitutions to forecast the deployment of very high-speed broadband (24 Mb/s and above), which generally requires fiber to or close to the customer's home. TFI's current forecast of subscribers to higher data rate broadband is shown in Figure 15. This forecast reflects the assumption that the average date rate increases by about 40 % per year, the typical rate experienced with analog modems (see Figure 16) and consistent with Moore's Law. To achieve these subscriber levels, a larger percentage of households must have very highspeed broadband available. Figure 17 shows the minimum availability to support the subscriber forecast, which provides a reasonable scenario for fiber deployment.[4)]

Caveat

We have had good luck forecasting substitutions that have not started yet. For example, the early HDTV, broadband, and SONET forecasts shown above have proven reasonably accurate. However, this type of forecasting is inherently uncertain because we have four basic questions:

- Will the new technology be successful at all?
- When will it begin to be adopted?
- What is the ultimate penetration?
- What will be the rate of adoption?

Drivers and constraints

A method we have found extremely useful in addressing the four questions listed above involves listing the drivers and constraints for the substitution. For example, the drivers for VoIP include:

- The growth of data traffic relative to voice traffic
- The growth in broadband access
- The overall improvement in Internet performance
- VoIP's ability to use generic software and hardware
- The avoidance of subsidies, taxes, and access charges

[4)] *The quantitative relationship is based on analogies to other adoptions, specifically, cable television, pay cable, and pay-per-view, [6].*

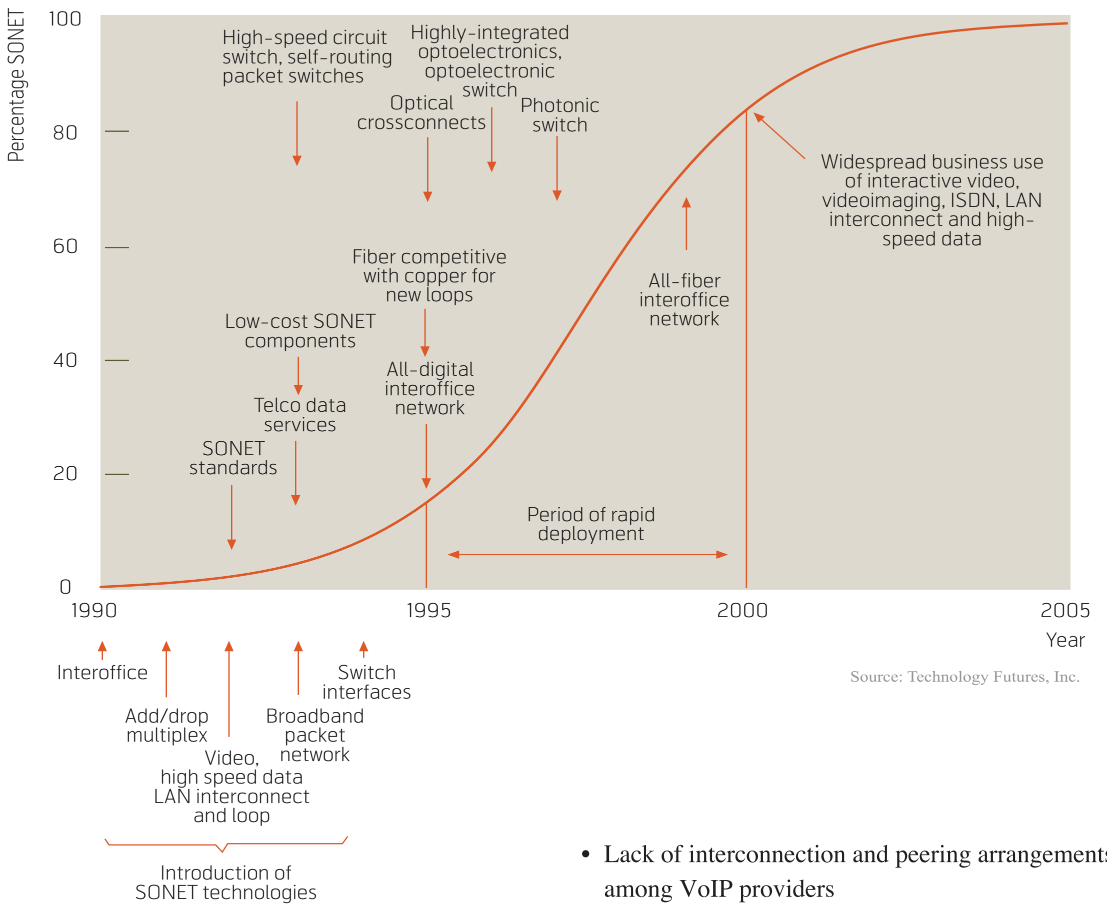

Figure 14 Adoption of SONET/SDH (1989 TFI Forecast) [13]

- The ability VoIP provides to integrate voice with other applications such as instant messaging, web conferencing, and call center information
- The potential to be a common denominator for a number of different voice standards
- The potential for quality exceeding toll-grade telephony
- The potential for greater privacy

Working against the drivers are a number of constraints on VoIP adoption, including:

- Some types of VoIP require that the user has Internet access
- Some types of VoIP require broadband access
- Potential delays, restrictions, and cost burdens to add surveillance capabilities required by law enforcement
- The need to provide location information for emergency services
- Lack of interconnection and peering arrangements among VoIP providers
- Reputation of having inferior quality
- Some types of VoIP are considerably more insecure and less private
- Defensive responses from traditional carriers

Clearly there are both significant drivers and constraints for VoIP adoption. The first question to ask is: What is the balance? In the case of VoIP, the

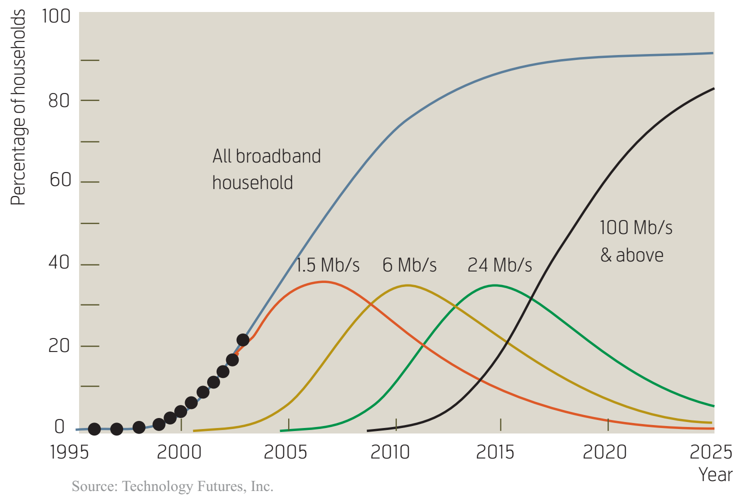

Figure 15 Broadband households by nominal data rate, percentage of households (US)

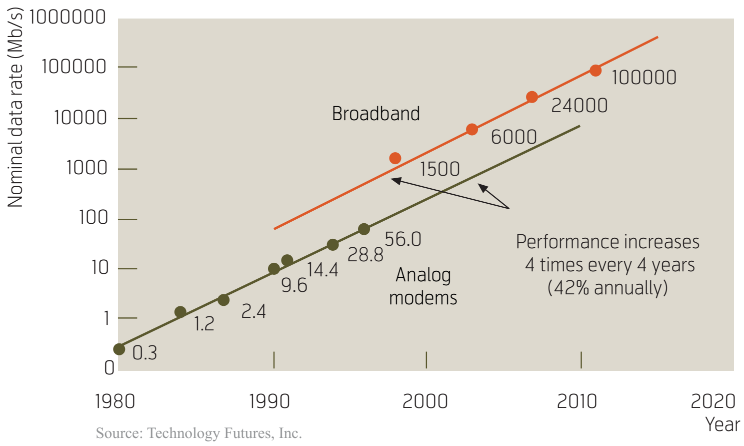

Figure 16 Trend in residential access data rates

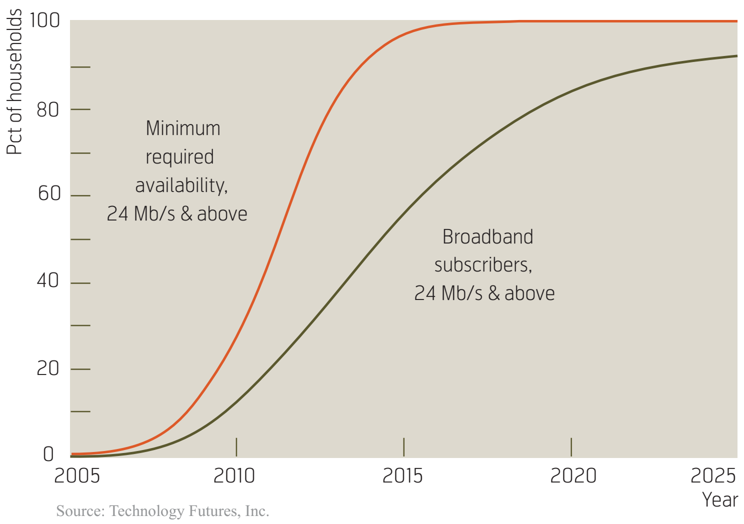

Figure 17 Broadband minimum availability – 24 Mb/s & above

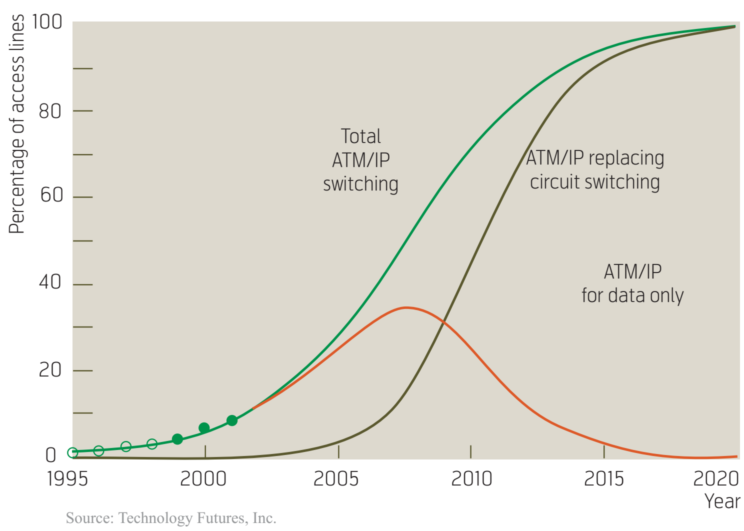

Figure 18 Adoption of VoIP for local telephone switching in the US (2003 TFI Forecast) [14]

drivers and constraints appear to be reasonably balanced. The second question is: Are the constraints likely to be overcome over time? For VoIP, it appears that all of the constraints are likely to be overcome within a few years and none of them stops progress in the meantime. This argues that the substitution of VoIP for traditional circuit switching will indeed take place, but not overnight, and will follow a typical, moderate substitution pattern such as the one shown for US telephone operators in Figure 18. For situations and applications where VoIP is most favorable – cross-border telephony, enterprise networks, and China, for example – we expect faster substitutions.

Multiple scenarios

We often use multiple scenarios to capture and convey uncertainty, especially for substitutions that have not started yet. For example, our distribution fiber forecasts have long used alternative scenarios. Figure 19 shows our 1989 forecast which had two scenarios: an aggressive one with US telephone companies quickly rolling out video services and a slower one reflecting the evolution toward broadband services in general. The late scenario still looks reasonable, and, while the early scenario clearly did not happen, it anticipated the plans (ultimately abandoned) formulated in the mid-1990s by several US telephone operators. Our post-1989 distribution fiber forecasts have reflected three scenarios based on alternative strategies for meeting the broadband demand. Figure 20 shows the current version of the scenarios, reflecting the fact that, in the US at least, there remains considerable uncertainty.

Using substitution models to forecast sales

The S-shaped curves, which measure penetration of the installed base, can be easily used to derive the distribution of *first time* sales (or additions) of the new technology. (It is the annual change in the installed base curve.) First time sales largely define total sales in the period before a replacement market develops. This curve is usually bell-shaped, although not necessarily symmetrical as shown in Figures 21 and 22 for the SPC switching and color TV examples. First time sales peak at the inflection point in the penetration curve. For example, the worldwide cellular penetration forecast (shown in Figure 6) implies the first time handset sales shown by the brown curve in Figure 23. Note that the brown curve clearly indicates that rapid growth in handset sales that occurred in 2000 was not sustainable.

Using substitution models to forecast growth rates

The annual growth rates of installed base and sales are often of interest. For example, it is common to speak of a market growing at X %. For services, the growth in the installed base is important (e.g. the percentage of households subscribing to broadband); for equipment sales, the growth of additions (e.g. sales of cellular handsets) is of interest. Figure 24 shows the percentage growth rate for the installed base assuming the Fisher-Pry model and no growth in the total market.

Note from the figure that the growth rate is high at first, but 20 % of the way through the substitution it falls off rapidly. Thus, the percentage increase follows a pattern opposite of the adoption curve – just when the adoption curve becomes steep, the growth rate plummets. Additions are getting larger, but from a larger installed base, which deflates percentage growth. (The falloff is even more dramatic with the Gompertz model or for equipment sales.)

When bad forecasts win

These observations about growth rates are of far more than academic interest because claims of rapid growth are made often and, when the underlying dynamics are ignored, big mistakes can be made. For example, an often cited contributing factor to the over-building of fiber facilities was the widely-publicized statistics and forecasts of the growth in Internet bandwidth. These held that Internet bandwidth was doubling "every 100 days" or "every 3 or 4 months" [7,8], equivalent to an annual growth rate in the neighborhood of 1100 %. Less fantastic were reports of doubling every 6 months, or 300 % annually [9].

Unfortunately for investors, they were all wrong. Actual Internet bandwidth growth has been closer to 100 % annually. The over-zealous forecasts assumed an exponential model with an extraordinarily high growth rate continuing into the future – "Moore's law on steroids" was the quip. However, the high early growth rate was fueled by millions of new Internet users coming on line in the 1990s. The forecast shown in Figure 25 (from a 1999 TFI study) made clear that the growth rate in first time users was declining and would decline in the future.

The high early growth rate from new users was amplified by the increase in bandwidth per user as people spent more time online and as their computers and applications grew more sophisticated. This factor, increasing roughly at the rate of Moore's law or about 57 % annually, also partially offset the inevitable falloff in the growth rate from new users, but not enough

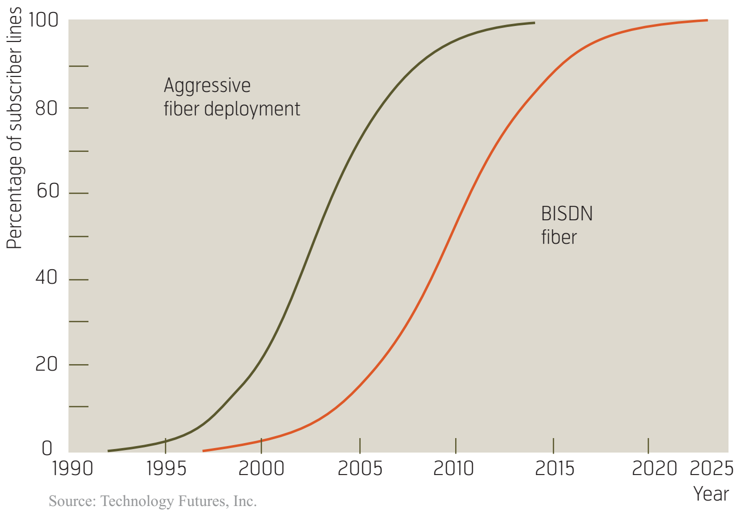

Figure 19 Alternative scenarios for distribution fiber in the US (1989 TFI Forecast) [15]

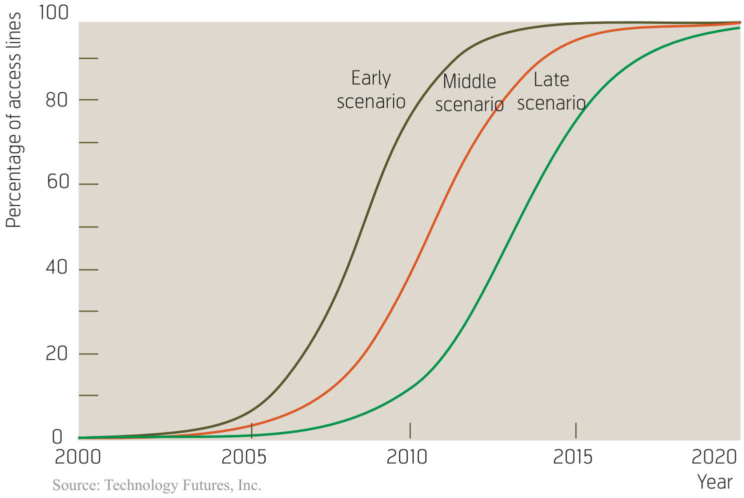

Figure 20 Alternative scenarios for distribution fiber in the US (2003 TFI Forecast) [16]

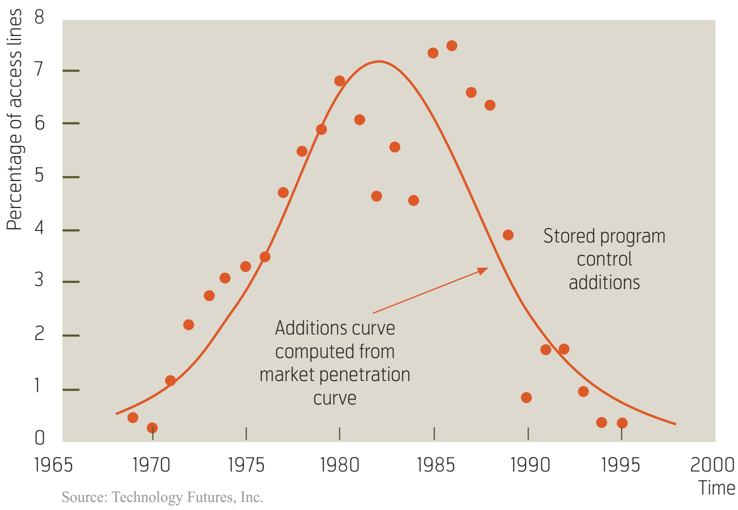

Figure 21 Additions of SPC access lines by local telephone companies

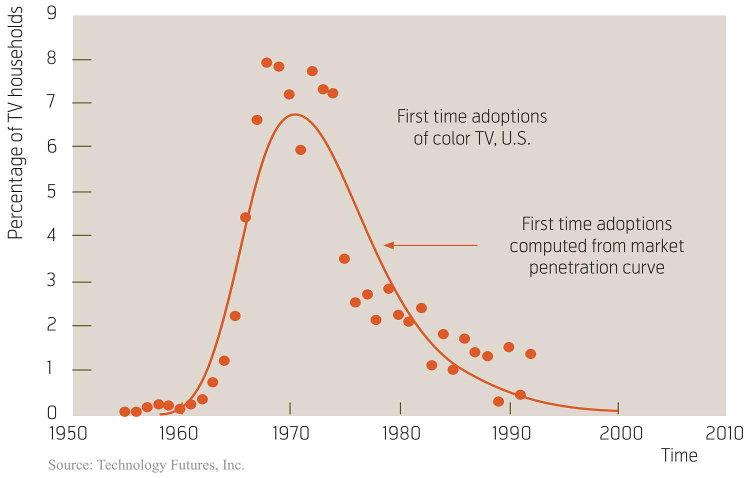

Figure 22 First-time adopters of color television

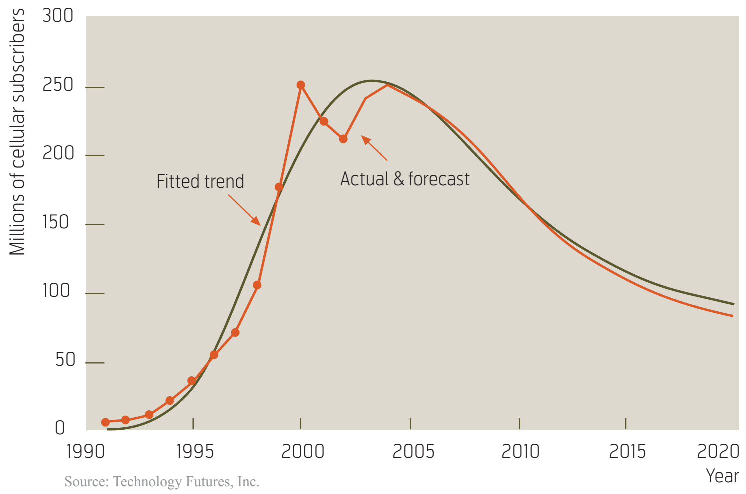

Figure 23 Worldwide first time cellular subscribers

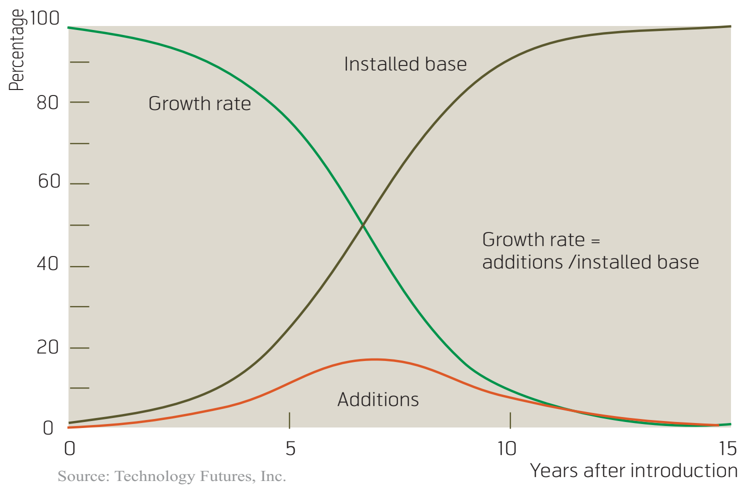

Figure 24 Percentage increase in new technology installed base (Fisher-Pry Model)

to sustain growth rates of 300 % and more, as shown in Figure 26 (also from the 1999 TFI study).[5)]

Conclusions

We have shown a few representative examples of telecommunications technology forecasts. There are many more that tell much the same story. There are several points that we have not mentioned or that we should reemphasize:

Although the methods are simple there can be complications in practice: multiple substitutions, market segmentations, aggregation issues, linked substitutions, and resource constraints, to name a few. These can be handled with extensions to the models.

There remains considerable uncertainty, especially when the substitution or adoption has not started yet. Multiple scenarios are useful in addressing and conveying uncertainty.

A drivers and constraints analysis helps address key issues such as a technology's likely success, ultimate market, introduction time, and adoption rate.

Forecasting how fast a new technology will replace an old one is much easier than forecasting which of two new closely competing technologies will win. The latter relies more on qualitative methods and considerable luck. For example, we are reasonably certain that by 2015 most households in the industrialized world will be served by distribution fiber. But the technology choice for the final link is far from settled: VDSL on copper cable, fiber PONs (one of several varieties), wireless (again one of several varieties), coaxial cable, and electric power lines are all candidates.

Most of the examples here are from the US, but the methods have been used everywhere. The starting points, rates of substitution, ultimate penetration points, and technology choices vary, but the basic principles of technology adoption appear to be fairly universal.

The mathematical modeling is only a small part of the forecasting equation. Even largely quantitative forecasts like the ones shown here require substantial qualitative work. Forecasting is seldom a "turn-the-crank" process, and forecasting technology adoption is no exception.

5) *Another problem was poor analysis of the historical growth rate. Individual Internet service providers might experience an extremely rapid growth spurt and in the very early days of the Internet the growth rate was extraordinary. But average growth rates across the Internet and over the 1990s were more moderate.*

In summary, our experience with technology forecasting in telecommunications has been excellent and we continue to use the same basic approach and methods. The Five views gives us the big forecasting picture and the Fisher-Pry and Gompertz models give us the quantitative forecasts that our clients need. Combined with good judgment and knowledge of the industry, this relatively simple approach has usually outperformed industry wisdom and the guesses that often pass for market forecasts. Anyone whose future depends on technology markets will find technology forecasting extraordinarily useful both in gaining insight and understanding, as well as in decision making.

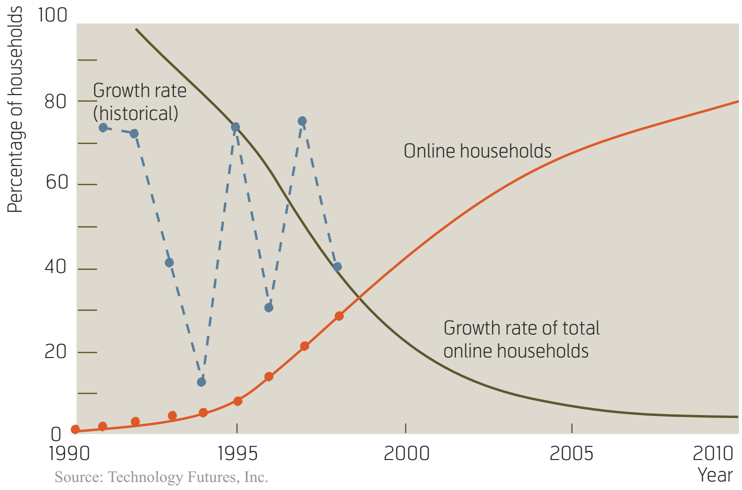

Figure 25 Growth rate in broadband subscribers (1999 TFI Study) (From 1999 TFI private client-sponsored study)

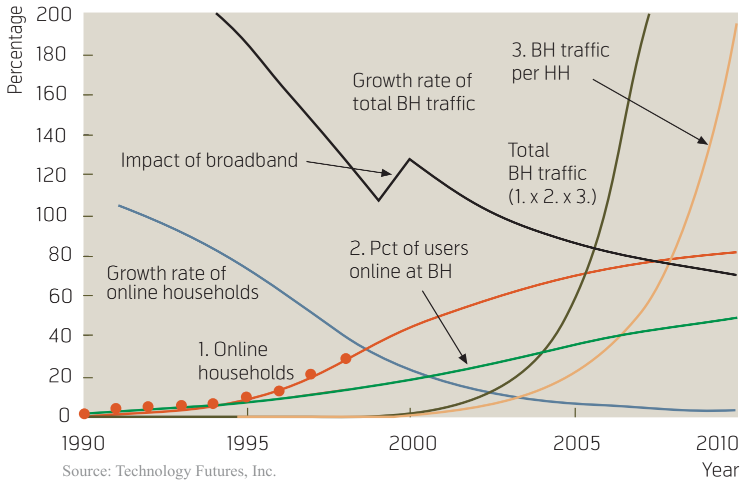

Figure 26 Bandwidth forecast accounting for decrease in online user growth rate (1999 TFI Study) (From 1999 TFI private client-sponsored study)

References

1 Hill, G C. Consultant's Call: Lawrence Vanston Makes Some Pretty Bold Predictions for the Future of Telecommunications. He Has Been Right Before. *The Wall Street Journal,* September 21, 1998.

2 Vanston, J H, Vanston, L K. Testing the Tea Leaves: Formal Methods for Evaluating the Validity of Forecasts. *Research Technology Management*, September, 2004.

3 Vanston, J H. Better Forecasts, Better Plans, Better Results. *Research Technology Management*, January/February, 47–56, 2003.

4 Vanston, L K, Vanston, J H. *Introduction to Technology Market Forecasting*. Technology Futures Inc., 1996.

5 Fisher, J C, Pry, R H. A Simple Substitution Model of Technological Change. *Technology Forecasting and Social Change*, 3, 75–88, 1971.

6 Vanston, L K, Marsh, J A, Hinton, S M. *Telecommunications for Television/Advanced Television,* p 123–144. Austin, TX, Technology Futures, Inc., 1992.

7 John Sidgmore [then President and CEO of UUNET/WorldCom]Says Internet Will Consume Entire Telco Industry. *ISP News*, September 29, 1998.

8 *Technology Forecast: 1999*. Pricewaterhouse-Coopers, October 1998.

9 Britt, P J. AT&T Revamps Spending Focus. *Telephony*, March 8, 20, 1999.

10 Stordahl, K, Kalhagen, K O, Olsen, B T (Telenor). Access Technology Demand in Europe. *International Communications Forecasting Conference*, San Fransisco, June 25–28, p 22, 2002.

11 Vanston, L. *Forecasts for Internet/Online Access.* Presentation to 17th Annual ICFC Conference, Denver, Colorado, June 15–18, 1999.

12 Vanston, L K, Rogers, C, Hodges, R L. *Advanced Video Services – Analysis and Forecasts for Terrestrial Service Providers*, p 106. Technology Futures Inc., 1995.

13 Vanston, L K. *Technological Substitution in Circuit Equipment for Local Telecommunicatitons,* p 104. Technology Futures Inc., 1989.

14 Vanston, L, Hodges, R L. *Transforming the Local Exchange Network: Review & Update*, p 37. Technology Futures Inc., 2003.

15 Vanston, L, Lenz, R C, Wolff, R S. How fast is new technology coming? *Telephony*, September 18, 1989.

16 Vanston, L, Hodges, R L. *Transforming the Local Exchange Network: Review & Update*, p 67. Technology Futures Inc., 2003.

Dr. Lawrence Vanston is an internationally recognized authority in the use of technology forecasting in the telecommunications and other high-tech industries. As president of Technology Futures, Inc., Dr. Vanston has been monitoring, analyzing and forecasting telecom technologies and services for more than 20 years. Subject areas include broadband access, VoIP, fiber optics, advanced video services, and wireless communications. An expert on the impacts of new technologies and competition on telephone networks, he often testifies before government agencies. In addition to enhancing planning and strategy, Dr. Vanston's forecasts are often used for estimating depreciation lives and valuations of telecom assets. Before joining Technology Futures in 1984, Dr. Vanston spent four years with Bell Labs and Bellcore in network planning. His academic achievements include an MS and PhD in operations research and industrial engineering, both from the University of Texas at Austin.

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Mr. Hodges is a member of the Institute of Electrical and Electronic Engineers (IEEE) and served as Vice-Chairman of its Technology Forecasting and Assessment Committee. He is also a senior member of the Society of Depreciation Professionals. Mr. Hodges holds a BS from Georgia Southern University in Industrial Management and Technology.

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