Practical Tips for Forecasting New Technology Adoption

LAWRENCE K. VANSTON

Lawrence K. Vanston is President of Technology Futures, Inc.

The pattern by which new technology is adopted is reasonably well-understood and, assuming there is data, there are mathematical models and methods to help forecast. However, many of the most strategic forecasts involve not much data and lots of uncertainty. There are 'big' methods – alternate scenarios, for example – to address such issues, but sometimes the practitioner needs to make a good forecast quickly and with few resources. In the process, the same issues often come up. Some examples: When will a new technology be introduced? Will anyone adopt it? If so, how many and how quickly? What are the factors of success? How long before the technology is obsolete? Which of two or more technologies will win? Each of these questions gives rise to other questions, the answers to which enable a good forecast. Or, in some cases, the answers lead to the conclusion that a definitive forecast would be premature. This paper provides examples, philosophy, and practical advice for addressing these questions so that quick – and dirty – forecasts are long-lasting and beautiful.

This essay is based on a talk I have been giving for 15 years on practical tips for forecasting new technology adoption. It has not changed much over the years, mostly because the basic principles have not changed and because we have had continued success applying them. It all started on the last day of a five-day forecasting seminar where we taught twenty or so methods. A student asked, with apparent frustration, "But how do you *do* a forecast?" My first (silent) reaction was, "Where have you been the last five days?" But what he was really asking was, "How do you get started? How do you decide what methods to use? What's the plan?" That launched an impromptu soliloquy which then became a routine talk.

The answer to the student's question depend on many things, but there are a few fundamental questions that usually come up. If you can answer those questions you will have both a good forecast and a good understanding of the situation. A short list of these questions follows:

- Will the technology be adopted by the market?
- How big is the potential market?
- When will the technology be commercially available?
- How fast will the technology penetrate the market?
- What are the factors of success?
- How long before the technology is obsolete?
- How do you choose between competing technologies?

It turns out that each of these questions has another set of questions to be answered first, and perhaps another set of questions for each of those. So really it boils down to answering a lot of questions.

The first four questions address the new technology generally, without regard to specific strategies, brands, and winners and losers. We refer to the answers to these as the general technology adoption forecast. These questions are reasonably tractable and are treated in Part 1. The second two questions address the factors of success in adopting new technology. They are more subjective and are treated in Part 2. The last question involves picking winners and losers. This is often the toughest question because it involves intangibles and unknowns. It is treated in Part 3.

Part 1 The General Technology Adoption Forecast

The answers to the first four questions, in a nutshell – How sure? How much? How soon? and How fast? – can be visualized with a graph like Figure 1, and, in fact, we often display the final forecast in just this form.

To help answer these questions, we always start with a technique that I call drivers and constraints.[1)] You will also see some variant of this in most good analyst reports. It's very intuitive, really basic, and absolutely essential. In a nutshell we try to answer the following questions:

- What are the drivers for adoption?
- How strong are they?
- What are the constraints on adoption?
- How strong are they?
- Can they be overcome?
- What is the balance of drivers and constraints?
- Will this change and, if so, when?

1) *Drivers and constraints is very similar to a more general approach called force field analysis. Call it what you like, but do it.*

 ISSN 0085-7130

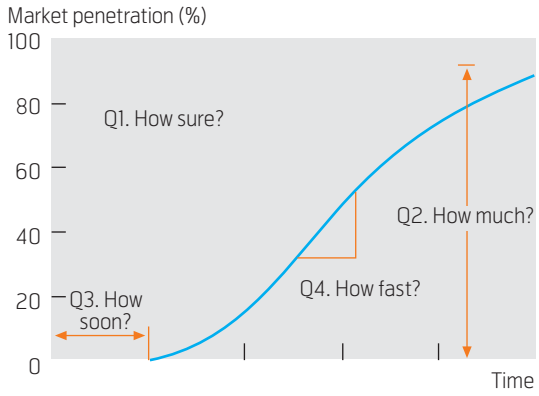

Figure 1 Questions for the general technology adoption forecast

Drivers					
The technology will save someone money					
How much?	1 A little	2	3	4	5 A lot
Type of savings?	1 Operating	2	3	4	5 Capital
When?	1 Future	2	3	4	5 Now
How sure?	1 Uncertain	2	3	4	5 Certain
How complicated?	1 1- or 2-off	2	3	4	5 Direct
The technology will make someone money					
How much?	1 A little	2	3	4	5 A lot
How sure?	1 Uncertain	2	3	4	5 Certain
When?	1 Future	2	3	4	5 Now
The technology solves someone's problem					
Recognized problem?	1 No	2	3	4	5 Yes
Size of problem?	1 Little	2	3	4	5 Big
When?	1 Future	2	3	4	5 Now
The technology provides someone satisfaction					
Tangible value?	1 No	2	3	4	5 Yes
Recognized value?	1 No	2	3	4	5 Yes
When?	1 Future	2	3	4	5 Now

Figure 2 Typical drivers

- What are the important areas of uncertainty that need to be resolved?
- How can these be addressed to everyone's satisfaction?

There are many types of drivers and constraints and they are often unique to the situation at hand, but there are some that usually come up. Figures 2 and 3 illustrate some typical drivers and constraints and some ideas on how to assess their strength.

Although I am the quantitative type, I generally do not strain to come up with an overall quantitative score for the drivers and constraints. If my intuitive scale tips strongly against the technology, I conclude that its chances are marginal at best. Video telephony fell into this category until only recently, when the constraints finally became weak enough to be overcome. If my scale tips strongly in favor of the technology, I estimate optimistic forecast parameters and move on to other issues regarding the technology. Broadband access was a good example of this. If my scale leans one way or the other, or gently rocks back and forth, or is stuck in the middle, then I know I have an interesting forecasting problem.[2)] Usually the key issue is whether and when the constraints will be overcome and/or when the balance of drivers and constraints change. Usually there will be one or two key areas of uncertainty or controversy and much effort will have to be devoted to addressing those areas.

A good illustration of drivers and constraints from my own experience can be found in forecasts TFI performed in the early 1990s regarding the adoption of high definition television (HDTV) in the US. When we did our first HDTV forecast in 1992[3)], the US Federal Communications Commission (FCC) was considering five different standards from different companies and consortiums and a decision was expected in late 1993 or early 1994.

The strongest drivers for HDTV were better resolution, higher quality, and a wider-aspect ratio which was more suitable for movies and sports than standard TV. Other drivers were the interest of TV manufacturers for a compelling new product, the US government's desire to regain competitiveness in consumer electronics and technology in general, and potential synergies between computer monitors and HDTV sets.

2) *If you are too young to remember real analog balance scales, you'll have to use your imagination here. For reasons I cannot explain, I like visualizing a scale. You may prefer to visualize the back and forth of opposing forces, perhaps a rugby scrum, or an American football line of scrimmage, or a tug-of-war.*

3) *Lawrence K. Vanston, Julia A. Marsh, and Susan M. Hinton,* Telecommunications for Television/Advanced Television: Forecasts of Markets and Technologies, *Technology Futures, Inc., 1992.*

None of these drivers was particularly strong at the time. Many people who saw HDTV demonstrations professed to not see much difference in quality. Cable television, although still not perfect, had corrected many of the quality issues inherent in over-the-air analog TV. There were already ways to compensate for the difference in aspect ratios between movies and TV, and wide-screen sports was an attractive promise still far from reality. Most analysts felt that the higher resolution would matter only at very large screen sizes, which would severely limit the HDTV market, perhaps to that of projection TV, which then comprised about 10 % of US households.

We did not completely agree with this assessment. Since there was, in fact, a major difference in resolution, once there was a product to sell, the talents of the marketing world would be easily applied to make people appreciate it. Likewise, the value of the wide-aspect ratio for movies and sports would be plain to people once they were in the showroom. Also, the emergence of multi-media meant that text on television would be important in the future. Text is horrible on analog TV no matter how big the screen is or where you are sitting. Finally, we were not convinced that the value of HDTV was limited to large screens even for normal TV viewing, especially since the cost differential with analog would probably be less for smaller screen sizes. Maybe people would not rush out to replace their small screens with HDTV, but when the time came to replace a broken analog set, they would probably replace it with an HDTV, we felt. In summary, although the drivers were weak, we concluded that they would strengthen over time.

Opposing these drivers were several strong constraints. First, there was the cost of HDTV sets, which were expected to range from $ 2000 to $ 5000 (or $ 3000 to $ 7500 in today's dollars). Second, there was the bulkiness of the sets. The display workhorse of the time was the Cathode Ray Tube (CRT). HDTV CRT sets with the wide aspect ratio and the size thought to be necessary for HDTV to be advantageous would weigh over 100 kilograms. The other major alternative at the time was CRT-based projection TV, but it had its own problems with bulkiness and weight. It seemed obvious that the solution to this constraint, as well as the cost constraint, was either Liquid Crystal Display (LCD) projectors, which were already available and rapidly improving, or LCD or plasma flat-panel displays that were under development. We concluded that, without successful and economical flat-panel displays, HDTV would be limited to the historical projection TV niche.

Another major constraint was the availability of HDTV programming. The infrastructure for producing HDTV programming – cameras, processing equipment, video tape equipment, know-how – would all have to be acquired by the industry. Lack of programming had crippled color TV in the 1950s, and there was concern that the same would happen with HDTV. We felt that concern was valid, but overblown because of the vast library of movies – ideal for HDTV – that was already available. (In the 1990s people watched movies on TV; in the 1950s, when color TV was introduced, they did not.)

The program delivery infrastructure was another constraint. Television stations and cable television companies would have to invest in new transmission equipment. This is true of most communication technologies, so it is not in itself a show-stopper, but the industry would have to see the opportunity in HDTV, or be given incentives (as turned out to be the case with broadcasters) to make the investment. We also

Constraints

The technology costs too much					
Will costs decrease?	1 A lot	2	3	4	5 Not much
The technology itself has limitations					
Are limitations real?	1 No	2	3	4	5 Yes
Can limitations be overcome?	1 Yes	2	3	4	5 No
External limiting factors					
How strong are these factors?	1 Weak	2	3	4	5 Strong
Can and will they change?	1 Yes	2	3	4	5 No
There is someone with something to lose					
How much?	1 A little	2	3	4	5 A lot
How powerful are they?	1 Weak	2	3	4	5 Powerful
Can objections be overcome?	1 Yes	2	3	4	5 No
Inertia against innovation and change					
Culture of potential adopters?	1 Innovative	2	3	4	5 Not innov.
Culture of potential suppliers?	1 Innovative	2	3	4	5 Not innov.
Satisfied with status quo?	1 No	2	3	4	5 Yes
Worried about future?	1 Yes	2	3	4	5 No
Competing solutions					
Are there competing solutions?	1 No	2	3	4	5 Yes

Figure 3 Typical Constraints

ISSN 0085-7130

believed that HDTV VCRs (and later DVDs) would give consumers a reason for acquiring HDTV sets, even without broadcast programming.

There were other constraints, but these were the major ones. There was no question that they would have to be overcome before HDTV would be widely successful and we thought they would be overcome in time. The only exception was the requirement that economical flat panel HDTV displays would become available. They could start out very expensive, but would have to follow a typical price decline pattern comparable to color television and other consumer electronics. See, for example, Figure 4. This was the major area of uncertainty to be addressed through research. That research revealed that R&D was being funded by the market leaders, significant progress was being made and more progress was expected. While no one expected flat-panel displays to follow the improvement rates typical of semiconductor microchips, there appeared to be plenty of room for cost improvements. Thus, we concluded that (a) HDTV was likely to be successful, and (b) it would ultimately be a mass market item like color televisions. We also reached the preliminary conclusion that, given the initial status of weak drivers and strong constraints, HDTV would take some years to reach the market and that it would not be an overnight sensation, but would have a moderate adoption rate.

More on Estimating when a Technology will Become Commercially Available

Although the names and details vary by industry, most innovations go through a process of discovery or development of concept, laboratory demonstration, field trials, and early commercial trials, before they are generally introduced to the market. Once you understand this process for the industry of interest, answering the following questions will help answer the 'when?' question:

- Where in the development process is the technology now?
- What steps must still be completed?
- How long does it usually take to go from here to commercialization?
- Can and will they be compressed?
- Who else is working on the process?
- What resources are there?
- What problems are likely to come up?
- How fast can these be overcome?
- Are there parallel developments or required conditions for commercial success?
- When will the market be ready for the technology?

Returning to our HDTV example: In 1992, the year of our first HDTV study, digital HDTV was in the laboratory demonstration phase at an industry-sponsored test lab. As noted above, the FCC was analyzing the results and was expected to decide on one of them in late 1993 or early 1994. Based on analogies with B&W and color, we estimated that HDTV receivers would enter the marketplace sometime in 1994 or 1995. From there we estimated that it would take four or five years to reach 1 % penetration. Thus, our estimated 1 % point was mid-1999. This was based on a compromise between the two to three years it took black-and-white TV, VCRs, and CD players to reach 1 % penetration and the eight years it took color TV (see Figure 4 again), HDTV's closest analogy. Again, we felt that lack of programming was much less a problem in the 1990s for HDTV than it was in the 1950s for color TV.

Perhaps we should have spent more time researching the 'problems likely to come up' question. As it turned out, in 1993, elements of several of the individual proposals for HDTV standards were combined to form a "Grand Alliance" digital system. Testing of the new system began in early 1995, the year of our second HDTV study[4]. In that study we estimated standards approval in 1996, commercial introduction in 1997, and 1 % penetration by yearend 2000, a year and a half later than estimated in 1992. However, before final approval the computer industry intervened, demanding progressive instead of interlaced scanning. The result was further delay. After a compromise was reached in late 1996 to allow both types of scanning, the FCC approved the standard on December 24, 1996, the first HDTV sets were intro-

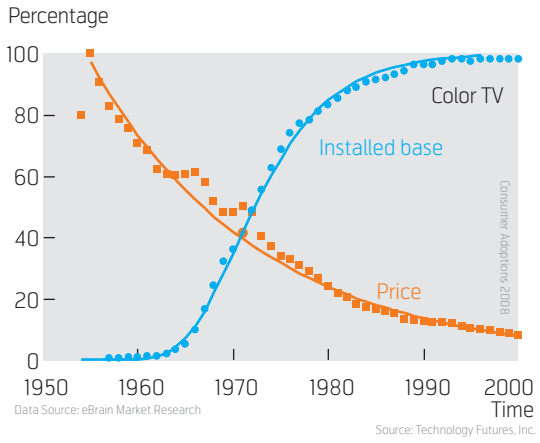

Figure 4 US Color Television Adoption

4) *Lawrence K. Vanston, Curt Rogers, and Ray L. Hodges,* Advanced Video Services: Analysis and Forecasts for Terrestrial Service Providers*, Technology Futures, Inc., 1995.*

duced in 1998, and 1 % household penetration was reached sometime in 2001.

More on Estimating how Fast the New Technology will Penetrate the Market

The 2004 article in *Telektronikk* (Vol 100, No. 4) by Ray Hodges and myself covered this topic in considerable depth, so here I will just list some typical questions to ask yourself:

- What is the likely process of adoption?[5)]
- Based partly on the above question, what is the most appropriate model to use?
- What are the useful analogies and can we get data?
- Are there parallel technologies or conditions that will affect adoption?
- How will the relative strength of the drivers and constraints affect the adoption rate?
- What factors will affect the adoption curve? These might include reasonably tractable factors such as multiple technologies, market segmentation, geographical segmentation, constraints on capital, labor, or supplies, and pent-up demand. There are also more intangible factors such as quality of marketing programs, continued technical progress and cost improvement, or lack thereof, and last gasp advances in the old technology.

Returning again to the HDTV example: Both our 1992 and 1995 forecasts estimated that the adoption of HDTV from 1 % forward would follow the Gompertz model with the same rate as color television after 1 % penetration. This was an obvious analogy, but not without controversy. Many observers felt that the difference in desirability between HDTV and standard color TV was less than that between color TV and black-and-white TV. Our drivers and constraints analysis indicated that while that might be true in the mid-1990s, it was unlikely to be as true after HDTV was introduced. (Plus, I remembered early color TVs and they were not that great.) Also, color TV was one of the slower US consumer electronics, so using it was on the conservative side anyway. Finally, we did an analysis that even if people only bought HDTV sets when their analog sets broke, HDTV penetration would be consistent with the forecast.

Figure 5 shows the forecasts we made in 1992 and 1995 compared with actual penetration data to date. Both forecasts are approximately right, especially when you consider there was considerable doubt whether HDTV would be successful at all or whether it would be no more than a niche technology. The 1992 forecast was early because of the delays caused by the Grand Alliance tack and the battle with the computer industry. The 1995 forecast has been extremely close for the first five years of the actual substitution, so it appears so far that the color TV analogy was perfect. There is some indication that the substitution has accelerated recently – it is too early to tell whether this is a permanent change. If so, the actual trend going forward may be between the two forecasts.

Methods for General Technology Adoption Forecasts

Besides drivers and constraints, there are a number of other tools we often use. These fall into the following categories:

- **Research**. Research, lots of it, is required to identify the drivers and constraints, estimate their strength, and address the issues that surface. This certainly includes secondary market research and may include primary market research. It also includes research into the technology of interest, competing and supporting technologies, and expected technological progress. In-depth technical knowledge, or R&D experience, is not required, but a rudimentary understanding is. Also, I spend time researching the opinions of others regarding the technology.

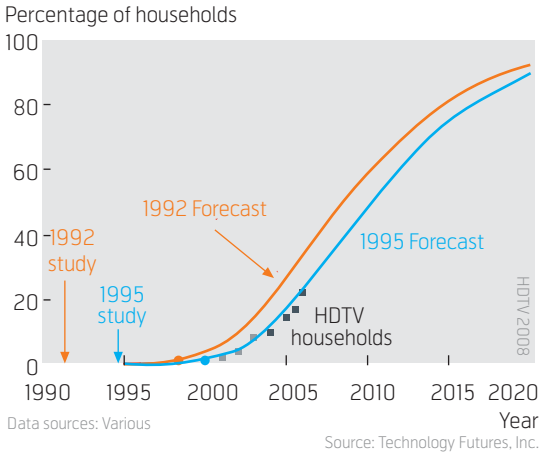

Figure 5 US HDTV: 1992 and 1993 TFI forecasts and actual data

5) *For example, will it likely be driven by mortality factors (eg. existing units breaking or wearing out), substitution (the new technology is superior to cause pre-mature change-outs), or diffusion (early adopters teach late adopters). Another example: Is it a consumer or a business adoption?*

ISSN 0085-7130

- **Expert Opinion**. Expert opinion can be useful, as long as you cast a wide net in finding experts. Expert panels, basic surveys, structured interviews, and Delphi surveys are all ways to elicit expert opinion. In my experience, I have found expert opinion most valuable in identifying issues, assessing technological constraints (and how they might be overcome) and estimating when technological milestones might be reached. I have found it less useful in estimating likelihood of market success or market size.

- **Group Methods**. Brainstorming methods are great for mining group intelligence to identify drivers and constraints, surface hidden issues and connections, and quickly get a feel for the issues. We typically stick to the relatively simple ones such as nominal groups and impact wheels.

- **Analogies**. I cannot recall ever doing a forecast without at some point relying on an analogy or two. Their application requires research and good judgment. Analogies are especially useful in computing time to market, how constraints are overcome, and determining adoption rates.

- **Economic Analysis**. Since many drivers and constraints are economic, some analysis of costs and benefits is often needed. However, the analysis is at a high level and only the most important variables are modeled. My main caution regarding economic analysis is to forecast changes, usually improvements, in the cost and benefit parameters.

- **Project Management Tools**. This may be a surprise entry on the list, but the process of getting from here to market introduction is like a project with activities, events, durations, costs, probabilities, dependencies, and critical paths. In this case, we use tools such as PERT/CPM for forecasting instead of management.

- **S-Shaped Curves**. I could not live without S-shaped curves. We use the Fisher-Pry and Gompertz models a lot, but the Bass model, full logistic, and many other models are widely used as well. Our above referenced article in *Telektronikk* covered this topic in depth so I won't say any more about it here, except to mention again that drivers and constraints and analogies are very helpful.

The Shoals of Technology Hypnosis and Technology Lethargy

People love to laugh about failed forecasts. On the overly pessimistic side we have the examples of Watson of IBM estimating in 1943 a world wide market of five computers and McKinsey & Company forecasting in 1980 a potential market of 900,000 cellular subscribers by 2000. On the overly optimistic side, I am still waiting for the flying car that was promised me when I was young. Or, much more seriously, in the late 1990s there were forecasts (that were demonstrably wrong when they were made) that Internet traffic would continue to double every several months. To avoid being laughed at (or worse) sometime in the future the forecaster needs to simultaneously avoid the shoals of technology hypnosis and technology lethargy. A simple drivers and constraints analysis does not guarantee perfection, but it will help you avoid the biggest mistakes. It is also a good idea to get the viewpoints of people from diverse fields and industries. Be open-minded. Good judgment helps too. That comes with experience and intelligence, but to the extent that good judgment reflects the balancing of many factors, drivers and constraints gets you halfway there.

Reality Check 1

Actually, my problem has always been more about getting laughed at in the present than the future. Here are a few examples from my career (so far):

- "[laughter], Larry, cellular will never replace landline telephone service. They are complements, not competitors."

- "[laughter], Larry, residential customers will never want broadband. They don't even want ISDN (residential ISDN was a big failure in the US) and our surveys indicate zero demand for broadband."

- "[laughter] Larry, we'll never retire those analog electronic switches; there is just no trigger for it. Digital switches are just a niche replacement for electromechanical switches."

- "[laughter], Larry, the Internet growth rate will never go down; you're missing the paradigm shift. Tell your client to go ahead and build that new fiber plant."

I never take the laughter personally because I understand that most people, especially experts, and even more especially executives, see things in the present. They are not forecasters. If they were, I wouldn't have a job. Replace the word "never" in their statements with "in the future" and they were right. My job is to, first, answer the four questions – how sure, when, how much, and how fast – and, second, over time, convince people that I am approximately right before it is too late. The second task is much harder than one would think. The reasons include:

- Regardless of the amount of work you do or how good your track-record is, you cannot prove the future. All you have is an educated opinion and a set of good arguments that someone has to listen to and understand.

- A pre-formed opinion, even in the face of educated opinion, can take time to overcome. People, especially executives, don't always have time to fully evaluate your arguments, especially when your conclusion is counter-intuitive or against conventional wisdom. After all, executives got where they are by having good intuition, ie. making good decisions on the fly, so be patient.

- There is always one more hole in your argument to be filled. Even if there isn't, and there is, someone will find one. So leave time for plugging holes.

- Nobody wants to hear bad news.

- Fundamental trends are the most powerful, but evidence of their impact can be slow. We first predicted that cellular phones would some day substitute for landline phones in 1988. Landline access lines in the US did not peak until 2000, and even in 2008, twenty years after the first forecast, less than 20 % of US household are cellular-only.

The last item usually works in our favor, because it means the forecaster may have time to save the world.

Ideas for Successful Selling

The following are some ideas for convincing people before it is too late:

- Distill conclusions into an easily communicated message. I have found that for each technology area, there are usually one or two charts that I use over and over again because they capture the situation in a nutshell. More importantly, other people are always borrowing them for their presentations.

- Build an understanding of technology market forecasting principles within your company through classes, presentations, special events, reports, newsletters, etc. This is in part to improve people's intuition regarding the future and to give people a reason to have confidence in forecasting.

- Start early, it takes a long time to turn around a big ship.

- Keep reminding people to never say 'never.' Be prepared to explain over and over again how you think things are changing as constraints are overcome and the balance of drivers and constraints change.

- Keep forecasts up-to-date. Among other things, it builds confidence that you are tracking the situation.

Depending on your personality, doing these things may not always be as fun as making good forecasts, but I have found that the satisfaction of being right pales in comparison to the satisfaction of seeing your company or your client be successful in part, maybe, because they believed you were right, or at least thought you might be right.

Part 2. Factors of Success

For every new technology I have been involved with, there have been many companies that have had the vision to pursue the technology. However, only a few have executed well enough to be successful. In one of our seminars, someone asked me which was more important, vision or execution? Obviously, they are both important, but the first thing a venture capitalist looks at in a new proposal, is not the great idea, but the management team. Of course, it is presumed a great management team will be visionary and only get behind good ideas that have been well thought out. So my answer was that it's important to have good vision and great execution.

One of my oldest and best clients always seems to be a step behind in the vision department, always makes incremental decisions, and always executes brilliantly. They have been very successful. Another of my oldest and best clients is what I would call visionary, makes bold decisions, and always executes brilliantly. They too have been very successful. Then there are those that were visionary and executed poorly. And those lacking vision that managed the downward spiral well. And those that didn't.

When I ask what are the factors of success, I am not referring to all the normal things like hard work, character, leadership skills, etc, but rather things involving markets and technologies. And within that category, things generic enough to apply to many technologies and specific enough to be useful (for example, not "Mom likes it" or "It tastes like apple pie").

The drivers and constraints analysis we did in Part 1 is useful in determining success factors. Anything that can be done to enhance the drivers is a success factor, as is anything that can be done to overcome the constraints.

Technologies Follow the Path of Least Resistance

To me, there are two most important factors of success. First, like electrons flowing in a circuit or rain falling on a mountain top and flowing to the sea, technologies follow the path of least resistance. You may believe with all your heart that 1 Gb/s fiber to every house is the optimal solution for broadband access. Or you may believe that wireless technology is the best access technology. You may believe that wireless mesh networks can replace metro fiber. But even if you are right, it doesn't matter because the people who spend the money don't care. In the US at least, companies report earnings quarterly and produce annual reports. They don't produce five-year, ten-year, or twenty-year reports. Executives that miss a quarterly earnings target risk their bonuses if not their jobs. Thankfully, they still make long-term investments but they tend to seek local optimums, not global ones (in a mathematical sense).

AT&T and Verizon's deployment of fiber in the loop is a good example of following the path of least resistance. Any good general technology forecast (see Part 1) will support their vision that much higher speed broadband is required and that video is an important service element. AT&T is deploying a fiber to the node (FTTN) architecture while Verizon is deploying fiber to the premises (FTTP). Both architectures meet the basic requirements forecast for the time being (a longer 'time being' in the case of FTTP), but neither is the ultimate architecture in the opinion of purists. Further, each company is, at this time, promising to deploy fiber in the loop to only about half of their customers.

Ironically, there has been resistance even to these plans. Both companies have had to struggle with investment analysts about whether even these incremental strategies would pay off. Verizon had the added burden of justifying their choice of the path of second-least resistance (only in terms of cost; in terms of the rapid rollout of video, it was the path of least resistance). In an incredible burst of long term thinking one analyst even opined that Verizon's (and presumably AT&T's) business case for FTTP should be burdened with the cost of converting the other 50 % that were not in the current plan.

I like the fiber in the loop example because it illustrates that even visionaries follow the path of least resistance and that the path of least resistance is not a path of no resistance. If the path of least resistance is hard, then the direct path to the optimum may be impossible.

Find the Natural Timing for the Technology

The other most important factor of success is finding a business strategy that matches the natural timing for the technology. As in romance, timing is everything. Too soon and your technology will not be appreciated by a critical mass. Too late and your product will not be needed anymore.

An example: Back in the mid-1990s, I remember advising a startup broadband equipment company not to gear up for mass production of a new broadband fiber in the loop technology. A major telephone company had been deploying the equipment in field trials. Knowing the typical telephone company time lines, telco propensity for doing trials as learning experiences, and recognizing that in the mid-1990s telcos really did not need broadband to most homes, I knew it was not too early to establish a position, but that it would be many years before they were selling the millions of units they thought they would be selling the next year.

Another example: After joining TFI in 1984, one of my first projects was to develop a computer-based business game based on the history of the RCA video disk. This turned out to be a classic example of having a technology in hand but waiting much too long to introduce it. RCA had developed a capacitance discharge technology in the early 1970s that allowed it to store a movie on a disk much like an LP record. However, it kept the technology on the shelf until the late-1970s when, needing a big success to re-establish a position in video, it rolled out the product. It was in fact a big disaster. Unfortunately for RCA, the rollout came just as Japanese firms finally perfected mass-production of VCRs for the consumer market. Had RCA introduced the video disk in the early 1970s, or even the mid-1970s, the window of opportunity may have been big enough to establish a major generation of video. By the late-1990s it was too late.

How do you know when the timing is right? Happily, this is easier in technology than love. The answer falls straight out of the drivers and constraints analysis and the adoption forecasts you did in Part 1. Those tell you the basic parameters you have to work with: How sure? How big? How soon? How fast? They also tell you what is important: strengthening drivers and overcoming constraints. A successful business strategy will match these to the company's strengths, weaknesses, and culture.

How Long before the Technology is Obsolete?

Speaking of timing, one question that often comes up is whether a technology under consideration will become obsolete before your investment is recovered.

ISSN 0085-7130 ©Telenor ASA 2009

This is relevant whether you are planning to produce the technology or use it. The question can be addressed by asking the following questions:

- Is there an identifiable replacement technology? If not, you are probably safe with the current technology, assuming you have been duly diligent in trying to identify a replacement. The time it takes to go from a concept to commercial introduction will likely provide a long enough window to recover your investment in the current technology. An exception may be Internet-based services where ideas can go from concept to product very rapidly.

- When will it be available commercially? See Part 1.

- How fast is it likely to substitute for your technology? See Part 1.

- Is there a large enough window to make money or to recover your investment in the current technology? The substitution curve from Part 1 for the replacement technology will help define the lifecycle of the current technology. Economic analysis based on that lifecycle will tell you whether the window is long enough.

- Will experience in the current technology pave the way for the next? Much of the cost of adopting a technology is cultural. If the current technology points to the future, it may make sense to abandon a dead end technology you currently have and get your organization valuable experience, or establish a position in the market, even if you might have to upgrade before the investment is amortized.

Reality Check 2

While answering all the above questions will point the way to successful strategies and help with evaluating whether a given strategy will be successful, it still does not address the myriad other elements of successful execution, including luck. This is the answer to the question, "Larry, if you are so smart at forecasting successful technologies, why are you not rich?" The reason is that I find technology forecasting more interesting than evaluating management teams; otherwise I would be a venture capitalist.

Part 3. Picking Winners and Losers

When the issue of which of two or more competing technologies will win comes up, the first question I ask myself is whether (a) they are competing technologies, or (b) one technology is substituting for another. If it is clearly a technology substitution of new for old, see Part 1. Otherwise, to get a feel for the issues I usually start with a table listing the advantages and disadvantages for each technology. This is basically the same as drawing a vertical line down a piece of paper and writing 'My Vacation' on the top and 'Beach' on one side and 'Mountains' on the other. Anyone can do it. As with drivers and constraints, we assess how the two technologies balance and ask whether the factors will change. A clear winner may emerge at this point, but, more often than not, the technologies roughly balance, especially if they have been in play for some time. If we haven't done it already, we might do a stakeholder analysis at this point to see if the mix of stakeholders in the various technologies tips the balance one way or the other. If not, we ask:

- Which technology best meets the factors for success? See Part 2.

- Does each technology have a natural market segment? I remember in the early 1990s an engineer questioned why I was doing a forecast on the future of fax when email was clearly a substitute for fax. I agreed with him regarding email replacing fax in the long run, but felt there was a large natural market segment for fax that would be of interest for most of the 1990s and that it would not be correct to treat email as a substitute … yet. At the time most business weren't on the Internet, and external email was all but impossible because of incompatible standards. It was also completely text oriented. Fax, on the other hand, was simple, intuitive, standardized, ubiquitous (in business), and was not limited to text. For a segment of the market – scientists, engineers, computer pros, internal corporate communications – email was an answer, but for a much broader segment it would be years before email was an alternative.

- If each technology has a distinct segment, how long can the market sustain both technologies? This question is much like determining when a new technology will be introduced and you can apply the same approaches to getting answers. For fax and email, the answer was about a decade.

- Are these competing technologies or brands? For example, back in the mid-1980s, I was in charge of personal computers at TFI. We were an IBM PC shop running Microsoft DOS, which had a command line use interface. One of our hip communications professionals, an employee I'll call Christopher, was lobbying me to convert TFI to the Apple Macintosh which had a cute little Graphical User Interface (GUI) that, in fact, I really admired. But Apple was very proud of their technology and priced accordingly, so I told Christopher, he could have one, but we were not going to convert all of

TFI. Cleverly I thought, he suggested that I do a substitution forecast of Macs vs. PCs, which would clearly show that by the end of the life-cycle for a new computer, Macs will have taken over. I did the forecast, but added the few PCs with early versions of Windows to the Mac count to get a GUI total for the new technology. The old technology was PCs running DOS (without Windows®). Christopher was right about the end of command line interfaces, but not about PCs. My decision was to wait for Windows to mature and buy new PCs then. (Apple lovers: This was a business decision.) The more important point is that Apple's strategy of keeping its prices too high for too long, and waiting too long to finally license its GUI interface to other manufacturers, betrayed Apple's confusion of its products (an excellent computer and an excellent operating system) with a technology (GUIs) that was available to all and which they had, to be polite, borrowed from Xerox.

- Can early leads be overcome? Often one technology gets to market first and is assumed to have an advantage. However, there are plenty of examples where early leads have been overcome. The Windows vs. Mac example above is one. TDMA vs. CDMA is another. The analysis regarding timing helps answer this question. In general, the burden of proof is on the leader trying to make the case that the lead is unassailable.

Reality Check 3

If two or more technologies are serious contenders, and you have gotten this far, it is probably a close call on the tangible factors that are subject to analysis, forecasting, and estimation. Being a close call, intangibles and unknowns will likely push it one way or the other. These could easily be non-technological factors. Most people considered Sony's Betamax VCR technology to be superior the VHS VCR technology, but VHS won nevertheless. There are numerous explanations for why VHS won, which is instructive in itself. If it is difficult to assess the unknowns and intangibles in a well-known historical example, how can we expect to assess them reliably for the future?

Even if there were not unknowns and intangibles, there still is a fundamental problem with picking winners when there is a close call. (Here I will betray my doctoral training as an operation researcher.) As an example, consider the battle of the fiber technologies (FTTN, FTTP, FTTC, HFC, Active Ethernet, etc). I possess a model that perfectly identifies all of the pertinent parameters that might influence which technology wins: cost, bandwidth, reliability, etc. There are ten of these parameters. I have accurately measured the performance of each of five alternative technologies on a numeric scale for each parameter in a way that reflects its desirability. I know that each of these scales are linear, or if not, how to transform them to be so. I also know weights for each parameter that reflect the parameter's relative importance. I also know that the weighted parameter scores are additive so that I can compute a total score for each technology by taking its weighted average score across the parameters. (Actually, they are not at all additive, but I know a secret formula to combining them appropriately.)

I will sell you my model, but you might not want to buy it. Do I really know the performance of each technology? Maybe I couldn't find the information, maybe I misinterpreted it, maybe I made it up, or maybe somebody lied to me. Maybe I just estimated the parameter weights using my own set of priorities. Or maybe I did a focus group of telephone guys I know who rated things on a scale of one to ten based on their best guesses. And maybe my secret formula is my grocery list.

Anyway, suppose these fears are unfounded and you buy my model. The technology with highest score wins, right? Not so fast. The winner is not decided overnight, but over a period of years. I have been observing the battle of access fiber technologies for twenty years and it is still far from over. This means you would have to accurately forecast the performance of each technology against each of the ten parameters, as well as their relative weights, and input these into my model for each time period. That's at least forty parameters to forecast. (No wonder there always seems to be an access fiber technology du jour.) Plus, you'll need my supplemental model (extra) for computing how the trajectory of changing scores will determine the ultimate winner, assuming there is one. Things will get complicated because the parameter values and weights will be different for different situations, areas, companies, countries, or regions. (So, for example, it's not that either AT&T or Verizon is foolish in their choice of FTTN or FTTP, but that they are different and can both be right. Plus, either could change their minds as things change.)

The reality is that slight changes to any of the model assumptions could change which technology would win if it is a close call to start. Add to that the intangibles and unknowns and you have what is a fundamentally difficult problem. You may want to buy my model anyway, but you cannot count on getting a reliable answer to the question of which technology will win.

Which leads us to the conclusion that the correct answer is often "It's too early to tell", and the correct business strategy is to put off making an investment or pursue multiple technologies for a while in parallel. This is often awkward because there will be intelligent advocates on one side or the other that don't share your uncertainties and will wonder why you can't make up your mind. But you have made up your mind and you have to stress that "It's too early to tell" is a professional opinion.

Final Reality Check

Even with drivers and constraints, great research, and good analysis, you cannot guarantee you will be even approximately right. The future is, after all, inherently uncertain. And, as discussed in Part 1, even if you are approximately right and you do your best to convince others, they still might not believe you. And, as we saw in Part 2, even if you are right and they believe you, there is no guarantee that your company or client will execute an effective strategy. And even if they do, intangibles, unknowns, and bad luck may conspire against them as we saw in Part 3. In short, the reality is we cannot guarantee the future, nor guarantee success. All we can do is maximize the probability of success. In all realism, that is worth doing.

For a presentation of Dr. Lawrence Vanston please turn to page 28.

ISSN 0085-7130