FORECASTING and MANAGEMENT of TECHNOLOGY

second edition

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Chapter 1
Introduction

Chapter Summary: This chapter gives a preview of this book, its motivation, audiences, major themes, and differences from the first edition. It is intended to give the reader an overview and a framework within which to place the chapters that follow.

1.1 About This Book

The intent of this book is to make better managers for the twenty-first century. Almost any organization succeeds or fails because of the decisions of its managers. Evidence shows that the most critical role of managers is to anticipate and drive changes in both their organization and perhaps the world with which it interacts. For example, Henry Ford's decision to produce a motorcar for the masses dramatically altered life in the twentieth century. Technology is a primary cause of change. If managers are not successful in anticipating and rapidly adapting, the constantly changing environment will render their carefully designed structures unproductive. This is well known by the current managers of Ford, who have had to struggle for the company's survival.

The first edition of this book emphasized that technology is the key to productivity and change is a fact of life. Thus, technology managers must be able to forecast and assess technological change to obtain competitive advantage. Managers now embrace this view, and add global thinking and continuous, at times radical, technical change as essential survival skills. Much has been written about the potential and the difficulty of forecasting and managing technology as well as about the importance of knowledge as the basis of national, corporate, and individual prosperity. This book focuses on practical tools to produce information for making effective decisions about the future and on the actions needed to mold that information.

The intended audiences for this book range from upper-level undergraduate and graduate students to experienced managers: present and future decision makers who want more rigorous techniques to guide decisions rather than relying solely on intuition and conventional wisdom. The tools and discussions presented here should be accessible to those who have studied business or social science, as well as to those with science and engineering backgrounds. While some books treat technology as one factor in management, this book provides the tools to make future technology a major component of strategy development for both executive and operational decisions.

The tools presented here are consistent with those in the first edition; however, their context has been updated to reflect the complexities faced by today's global managers. Changes in this edition reflect progress in thinking about the management of technology. The book's most important enduring feature is its presentation of usable tools to aid in the assessment of technology and technological change. Most examples given in the first edition have been updated and new examples added. Software used in various calculations now emphasizes generally available packages rather than proprietary approaches presented in a toolkit. While the broad range of the impacts of technology is still addressed, this edition puts greater emphasis on the contexts within which managers make and implement decisions.

This book follows the approach most likely to be used by those who must develop forecasts of technology and act on their implications. The introductory chapters, Chapters 1, 2, and 3, address what technology forecasting is, its methodological foundations, the most frequently used methods, and structuring and organizing the forecasting project. In many cases, these three chapters introduce concepts that are more fully explored in the book as a whole.

Ensuing chapters provide additional methodological depth. Chapters 4 and 5 explore information gathering and some tools that can be used to analyze and generate results. Chapter 6 describes tools for analyzing information using techniques of simulation or modeling. Chapters 7 through 11 focus on the results of the forecast and show how they can be applied to reach conclusions about market potential, economic value, impacts of the technology, risk, and cost-benefit trade-offs. The book concludes with techniques and reflections for effectively implementing forecasting results. The appendix provides a case study demonstrating a complete life cycle of technology forecasting.

1.2 Technology and Society

While a lot of attention is paid to how technology affects society, those who manage technology and the businesses that use it must recognize that the interaction goes both ways. Society affects the paths of technological change, and many innovators have failed because they have tried to sell solutions to problems that their customers were not ready to solve. The time lapse between discoveries of new knowledge and commercialization can be short or long, depending upon the willingness of society to embrace the change. For instance, it took decades for television to really catch on, but social networking sites like Facebook have exploded, playing prominent roles in millions of lives within a matter of months. And while information technology could dramatically increase the efficiency and effectiveness of health care, medical professionals and institutions have been slow to adopt it. Yet the applications of new drugs, medical devices, and diagnostic equipment grow very rapidly as soon as they are available. Understanding the social and cultural dimensions of technological change is complex and uncertain, but technology managers must deal with the systems of forces that will affect the results of their efforts.

1.2.1 Social Change

Some forces that affect a new technology will be the traditional resource directions of the market, but others will arise from social change and related political forces. For instance, rapid rises in energy prices in the 1970s led to dramatic energy-saving innovations in the 1980s. The run-up in oil prices in the first decade of the twenty-first century had a similar effect, as evidenced by sales of hybrid cars and the development of other alternatives. In some cases, social changes open new opportunities. For instance, women's increased labor force participation created demands for time-saving appliances like the microwave oven. Today young people who once met in town squares or restaurants to socialize use the latest technologies to stay in touch via online and texting communities. Some social forces acting on technologies can be puzzling. Europeans reject genetic engineering of their food supplies but embrace irradiation for the sterilization of milk, while Americans have tended to do the opposite.

Social changes can produce political actions, such as government spending, subsidies, taxes, and regulations. The debate over stem cell research in the United States illustrates how values can put restrictions on government funding of research and slow change. The desire for energy independence has led to huge U.S. subsidies for corn-based ethanol plants and research spending on fuels from cellulose, trash, and algae. U.S. nuclear power generation was at first promoted and then stopped by major expensive regulatory requirements, but it may be promoted again in the twenty-first century. Of course, new technologies have their own impacts on markets, social movements, and government policies. The lines of causation go both ways, and easy generalizations are elusive. Islamic fundamentalist groups like the Taliban and al Qaida seemingly reject modern ways of life but have made very effective use of satellite phones, modern weapons systems, and the Internet. However, the complexities of these relationships do not reduce their importance to managers who must make decisions about technologies. This book will not provide the answers, but it will provide a framework for asking many of the right questions and organizing the resulting information.

1.2.2 Technological Change

The significant reduction in employment in the U.S. manufacturing sector illustrates the dramatic implications of the global impacts of technology. Conventional wisdom is that manufacturing is going offshore and that it is playing a declining role in the American economy. However, data from the Census of Manufacturers and the U.S. Bureau of Labor Statistics show that this is *not* what is happening. True, there has been outsourcing to both foreign and domestic operations by both firms classified as manufacturers and others in different classifications that formerly were integrated into manufacturing companies. However, output of manufacturing as measured by contributions to the gross domestic product increased by over 20% in the decade ending in 2007. While manufacturing employment fell by 24% over the decade, worker productivity went up over 58%. Increasing automation has meant that fewer workers are needed in manufacturing processes (Krugman and Lawrence 2008). Even outsourcing has been enabled by information technology. Firms that were once dominant but failed to anticipate and change with the opportunities offered by new technologies have discovered their vulnerability. Clearly, advances in technology have totally transformed the way we make and distribute goods.

The issue of vulnerability is even clearer if one considers the threat posed by radical innovations. Typically, successful organizations engage in continuous innovation that improves technologies by a few percent every year. If a radically different approach emerges, existing producers often find reasons to consider it irrelevant. Examples abound. In the mid-twentieth century, for instance, producers of electronics products like stereos and TVs used vacuum tube technology that they consistently and incrementally improved. They viewed the first Sony transistor radios as cheap novelties. However, it was not long before those producers struggled and failed while Sony grew to global dominance. American automobile producers initially ignored technology changes in production. Other examples could be drawn from the computer industry, where the personal computer completely transformed a relatively young industry, or the steel industry, where new methods destroyed the dominant leadership of an old industry. Retailing is not manufacturing, but Sam Walton's Walmart showed how technology could completely change that business. And finally, throughout the twentieth century, North American agriculture experienced similar declines in employment while production capabilities rose.

As Clayton Christensen described in *The Innovator's Dilemma: Why New Technologies Cause Great Firms to Fail* (Christensen 1997), the very strengths that make an organization successful can become obstacles to success in a new technology paradigm. Sometimes the problem is arrogance. Sometimes it is the inability to quickly and smoothly adopt technical skills. Christensen and Overdorf (2000) described the demise of Digital Equipment Corporation (DEC), arguably the leading computer company in the 1980s but absorbed by Hewlett Packard in the 1990s. The personal computers (PCs) that ended DEC's dominance could easily have been designed by their talented engineers and scientists, and DEC had a great brand name and a lot of cash to shift into the new business. However, their internal operating procedures were designed to spend two or three years perfecting each new generation of mini-computer to be sold at a high profit margin to engineering organizations. By contrast, the PC business was focused on the assembly of outsourced modular components with rapid design for low-margin, high-volume sales to the masses of customers who went to retailers to buy them. It was not the basic technology of computers that defeated DEC; it was the whole range of technologies throughout the value chain from components to sales and service.

These examples illustrate what Schumpeter called *creative destruction* (Schumpeter 1937). The new products and huge increases in productivity resulting from technology advances should not be surprising. Robert Solow, Nobel laureate in economics, showed decades ago that much of the improvement in American living standards in the mid-twentieth century was due to technological progress. His work applied to other developed countries as well (Solow 1957). Increasingly, the job of effective managers has become to continuously find ways to make their currently profitable businesses obsolete and to position their firms to be dominant in the next wave of technology. For many, this is a process of continuous improvements. On the other hand, 3M Corporation has set a goal of 30% of all sales from products that are no more than four years old (Kanter, Kao, et al. 1997, p. 55; von Hippel, Thomke, et al. 1999).

Opportunities to innovate with new technologies will abound, but only those who can adapt to the unforeseen changes will be really successful. In his book *Mastering the Dynamics of Innovation* (1996), James Utterback concluded, “Innovation is not just the job of corporate technologists, but of all major functional areas of the firm.” In the case of radical innovation, he went on to say that “the responsibility of management is nothing less than corporate regeneration” (p. 230).

The next decade will present both opportunities and pitfalls for those who want to exploit new possibilities for technology. The recent period of rapid rise in energy prices seemed to make the development of biomass fuels, solar power, electric vehicles, fuel cells, and methods of increasing efficiency and conservation inevitable. Indeed, billions have been invested in ethanol and biodiesel production and in research on alternative energy sources. However, the credit crisis and the subsequent global recession have made the economic viability of new approaches much less clear. Similar fluctuations in expectations have affected many other technologies. At the same time, the growing global consensus about the impacts of human activities on global warming, as well as persistent concerns about terrorism and political insecurity, continue to motivate exploration and investment in more sustainable ways to live. Moreover, discoveries related to the human genome and nanotechnology seem likely to generate more commercial opportunities, and evolving computer and communication technologies keep opening new pathways for products and services. Expanding numbers of aging retirees and longer life expectancies in the developed world are creating greater demand for medical and day-to-day care. At the same time, Paul Polak (2008) and others are showing that the billions of barely subsisting people can use new, dramatically low-cost technology to improve their living standards and thus create markets for novel products and services.

The methods, tools, and perspectives of this book are useful to nearly every manager. In a world of rapid change and global competition, being the best at any management function will be a short-lived advantage. Effective twenty-first-century managers must constantly have a vision of the future that guides their actions today; we call this managing “from” the future. Only by managing from the future will they encourage the new ideas, develop the flexible processes, and invest in the collection and management of knowledge that will allow them not only to adapt and survive, but to be part of the changes that create that future. This book provides frameworks of thinking and practical tools to more systematically anticipate the road to a successful future.

1.3 Management and the Future

A standard college textbook defines management as

> A set of activities (including planning and decision making, organizing, leading and controlling) directed at an organization's resources (human, financial, physical and information) with the aim of achieving organizational goals in an efficient and effective manner. (Griffin 1999, p. 7)

This definition is a static way of looking at what managers do. Scholars of organizational economics point out that managers must assign rights to make decisions, decide on rewards for making and implementing good decisions, and implement ways to evaluate the performance of both people and business units (Brickley, Smith et al. 2004, p. 5). However, the context in which managers act has become both more intense and more complex. Virtually every business and many not-for-profit organizations depend upon technology strategy for survival. While some industries are called *high tech* even a supposedly low-tech business, like retailing, is dominated by companies like Walmart, whose strengths were built upon highly sophisticated systems for logistics and inventory management. Thus, all managers need to realize that technologies are pervasive in all of their activities.

Several decades ago, Peter Drucker (1985) talked about strategic planning, which he described in the following way:

> It is the continuous process of making present entrepreneurial (risk-taking) decisions systematically and with the greatest knowledge of their futurity; organizing systematically the efforts needed to carry out these decisions; and measuring the results of these decisions against the expectations through organized systematic feedback. (p. 125)

Drucker stressed knowing what the business was, what it would be, and what it should be. In subsequent years, major resources were poured into elaborate planning efforts, especially by large organizations. However, lessons from these planning exercises were seldom disseminated to day-to-day decision makers. Richard Florida and Martin Kenney (1990), among others, pointed out that in the 1980s, corporate America's bureaucratic approaches were ineffective in making their companies globally competitive. In fact, many bright innovators left large employers to launch new technologies in start-up ventures.

Today markets and technologies change so rapidly that even large companies look for entrepreneurial approaches that are simple to grasp and easy to change when external changes demand. Apple, amazon.com, and Google are cited as representatives of the new wave of management thinking. Wikipedia discusses, for instance, the novel lattice organization and the approach to problem solving used by W. L. Gore and Associates, a manufacturing firm (Harder and Townsend 2000). These firms and others are the laboratories for the new manager in a time of falling entry barriers, growing buyer power, and very efficient competitors fostered by the Internet. New management schemes reward employees for initiative, creativity, and *passion*, another word for *engagement*. A major concern of the new manager is how to get employees to become fully engaged in the firm's enterprises.

Guy Kawasaki (2004, p. 5) was particularly critical of large corporate planning activities in *The Art of the Start.* He pointed out that the typical corporate mission statement, the starting point for planning, often was a collection of meaningless generalities. He advocated that organizations search instead for a mantra—a few words that capture the essence of what the firm is trying to do in a way that will keep people focused and passionate. Whether the organization is an established firm or a start-up, its resources need to be applied with the flexibility to change with markets and technology. That flexibility is best used in a framework that provides for creative responses within a context of a strategic vision of the ultimate future goal.

The fact that corporations no longer place high value on complex long-range plans does not mean that they or start-up ventures can function well without a systematic view of the future to guide day-to-day decisions, as well as major investments, alliances, and other strategic decisions. Since technology is integral to almost all management activities, technology planning is not separate from overall planning. Planning begins with a vision of the future toward which the organization is moving. It also provides intermediate goals as milestones to assure decision makers that they are on the right track. Reaching those goals requires a strategy. For example, one might try to be the first to implement new technology so as to grow rapidly and assure a dominant market position. Or one could take the strategic position of letting rivals rush ahead to establish a market and reveal their vulnerabilities before moving in with superior products and services. These alternative strategies have very different implications for organizational tactics. The people who are attracted and assigned to various functions, and the resources that are deployed for them, will be subject to the strategy and tactics that are pursued.

1.3.1 Management and Innovation Processes

Presentation of the frameworks mentioned above requires some explanation of the processes used by managers to produce innovation. These processes range from strategic management to the specifics of scheduling resources and reviewing project performance. While complete coverage obviously is beyond the scope of this book, some discussion of management is needed to show how to implement the suggested approaches. Jay Conger (1998) has pointed out that leaders must be champions of innovation. Thus, the innovation process must begin at the top. Executives are responsible for developing and implementing strategies that lead to continuing success. The first requirement for this is vision, both of what the future holds and the role that the organization will play in that future. In addition to providing vision, leaders must align the organization's resources and mobilize as well as motivate people to meet the challenges of ambitious goals for the future they envisage. To provide direction for the use of resources, it is essential that leaders grasp the potential of incremental change and the threat that radical innovations, approaches, or products will change the market. Once the vision is embraced, it has to be implemented by tangible changes in processes and products.

Two decades ago, Richard Florida and Martin Kenney (1990) suggested that the belief that breakthroughs alone are sufficient to keep firms—and even nations—on a competitive footing is an illusion. They emphasized that better integration of shop floor activities with R&D, and empowering production workers to innovate, are critical. Much progress has been made on these fronts, as the previous discussion of manufacturing productivity noted. Designing for quality and efficiency, and applying tools such as those under the six sigma banner, have greatly improved American competitiveness. As new technologies rapidly become commodities, their production will still shift to the lower-cost regions of the world. However, products are increasingly becoming highly configurable to individual tastes and are changing so rapidly that innovation and production have become much more closely linked. Yet, the notion that high-technology breakthroughs alone bring great prosperity remains an illusion in most situations.

Timmons and Spinelli (2008) pointed out that Ralph Waldo Emerson's poem about the world beating a path to the door of the better mousetrap's creator is just not true. It generally takes years for discoveries to become innovations, and trying to force new technology to become a market success is extremely difficult. A manifestation of the difficulties of moving from breakthrough to commercial success is the small fraction of university research output that has actually produced new products or processes. There is a “valley of death” that seems to trap many great ideas and even patented inventions between breakthrough and production. There are technical and business reasons for this. Getting from the lab to a prototype can involve challenging creativity and effort that often does not excite world-class researchers, even when they have economic incentives. Moving from prototype to production versions generally implies another series of hurdles. Moreover, evidence shows that transforming new knowledge into a successful product or process must reflect the input of the ultimate customers. All of this requires a great deal of patience, persistence, time, and money.

1.3.2 The Role of Technology Forecasting

Forecasting has been done since people first started making long-term investments. The earliest farmers cleared land and planted because they expected to harvest. Certainly the pyramids and other ancient structures are testaments to the builders' belief that the world as the builders knew it would continue for a long, long time. The most fundamental forecast is that things will happen in the future in pretty much the same way they have happened in the past. While this is referred to as *naive forecasting*, it is still prevalent and powerful. How many companies or communities have delayed taking necessary actions because they believed that their businesses' way of life would not really change?

Extrapolation of the past to the future is an intuitive approach, and while it may be dangerous, it is often correct. Economics and other fields have built complex models of extrapolation, sometimes with hundreds of causal relationships. However, even these elaborate applications of sophisticated statistics estimate those relationships from historical data. Nonetheless, the dangers inherent in extrapolation are real. In 2008, the world experienced a financial crisis unlike any since the 1930s. Institutions and regulations had been established to prevent such a thing, and although there were regional meltdowns and Japan experienced a lingering financial malaise, the systems of the United States and other economic powerhouses seemed more than up to the task. Information technology and confidence enabled many innovations, and the whole world seemed to be booming as a result.

By the late fall of 2008, spring forecasts for a mild U.S. recession and continuing boom conditions in China and other emerging economies suddenly seemed wildly optimistic. With all of the powerful computer and information technology and the sophistication of world financial professionals, how could the outlook have shifted so dramatically? The quick answers include the volatility of human emotions and the fundamental requirement for trust to make the systems work. However, a brief examination of the triggers for the near collapse of the financial system is instructive for a discussion of forecasting. Investment banks had put together complex financial instruments based upon home mortgages so that institutions like insurance companies, pension funds, and banks could earn high rates of return. These instruments seemed secure because of the stature of the organizations that originated them. Therefore, institutions did a lot of borrowing to acquire them. Based upon data compiled since World War II, these schemes should have been safe. However, the problem with even the most mathematically elegant predictions is that things change. In this case, pressure for low and even zero down payment mortgages to encourage home ownership, and unwillingness to burden financial markets with rigorous regulation, spawned a boom in risky mortgages. Inevitably, the boom in home values peaked and, for the first time in most memories (and data sets), house values declined, destroying the security of the instruments and leading to solvency problems for financial institutions all over the world.

While the story of the 2008 financial disasters illustrates the dangers of extrapolation in a changing world, the lessons for technology forecasting are clear. In a world of rapid and dramatic change, it is hard to forecast. And it is even harder to forecast the progress of really new technology, because there are no past data upon which to draw and no real understanding of the impacts of the technology itself. Nevertheless, forecasts will be needed if planning is to be done and investments in innovations are to be made.

This book addresses the dilemma of adaptive management under rapid change, as described above. Forecasting technology certainly should use extrapolation, but there is much more that must be brought to bear to produce reasonable views of the future. For instance, qualitative assessments of the technology and analogies to other technologies with similarities will be needed, as well as structured approaches to gathering information on the technology itself and on supporting and competing technologies. Much of this book describes how the problems of forecasting technology can be formulated, how creative approaches can be designed, and how information can be explored, evaluated, and focused for useful decision making. At each step, the discussion will be framed by the strategic context in which the forecast will be useful. Understanding that context is crucial both for effective results and for scoping the investigation to meet time and resource constraints for good management decisions.

1.3.3 The Importance of Technology Forecasting

An important part of technology forecasting is to assess the impacts of implementing a new technology on both the firm and its external environment. Ignoring possible negative effects can have disastrous consequences for the firm as well as for people who are neither involved in decisions about the technology nor are likely to benefit from it. Societies around the world have reacted to such disasters by holding businesses accountable, even to the point of bankrupting them. Governments also have established rigorous regulations that can stifle change. It was probably fears of unintended consequences that stopped the growth of U.S. nuclear electricity generation. More and more regulatory requirements for design and operation apparently made the option uneconomic in the minds of electric utility executives. Requirements for acceptance and agency approval of such things as environmental impact statements also have been used to protect natural resources, important species, and public health. Unfortunately, the phrase *impact assessment* is often associated in business with notions of bureaucratic compliance. The principles and tools described here are motivated by a very different purpose, although they may be complementary to regulatory requirements.

Joseph Coates (1976), one of the pioneers in holistically viewing the effects of technology, advocated

> the systematic study of the effects on society, that may occur when a technology is introduced, extended, or modified, with emphasis on the impacts that are unintended, indirect, or delayed. (p. 373)

A “systematic” study involves an approach that is as orderly and repeatable as possible, one in which information sources and methods are defined. Although the study focuses on the “impacts” of the technology on society, a comprehensive study also will address the reverse effects of social forces on technological development. “Unintended, indirect, or delayed” effects extend beyond the direct costs and benefits traditionally considered in technical and economic analyses. Exhibit 1.1 captures the idea of indirect, or higher-order, impacts that are unanticipated.

Exhibit 1.1 Consequences of Social Networking Sites

First: People have a new way to connect with others all over the world.

Second: People are physically at home but are virtually engaged in cyberspace.

Third: The power of the Internet enables people to find others whose interests are aligned more closely with theirs.

Fourth: People find it easier and perhaps more enjoyable to deal with others on the Internet than to try to reinforce relationships with those around them.

Fifth: Internet relationships become more and more intimate with time.

Sixth: Increased divorce rates result when marriages are unable to adjust to spouses who meet their emotional needs on the Internet.

There are major global issues associated with development of technologies, some of which have been discussed for decades. For example:

- Global climate change, while still debated, is motivating policy changes that affect technology in many parts of the world.
- Energy sources and uses, as well as their economic and geopolitical implications, continue to dominate thinking and decision making by nations, firms, and individuals.

- Pollution continues to plague cities, especially in the countries with emerging urban economies that continue to attract millions of people to unhealthy environments.
- Finding adequate water resources is a problem for both the rich and the poor.
- Technology has extended life and created health care cost burdens for even the richest societies.
- Falling birth rates have caused shortages of young people in countries like Japan, while the poorest of the poor continue to have too many children born and too many die.

The continuing public debate over global warming shows that even determining past causes and effects is hard. So, what hope is there to determine future ones? *Certainly there is none of providing certainty*.

There is little hope of predicting the precise effects of a change in technology, even less of predicting the magnitude or timing of those effects, and still less of foreseeing the manner in which the effects will interact among themselves and with other forces. Instead of trying to achieve certitude, it is more helpful to seek to reduce the uncertainty and to know more about the interrelationships of the systems involved. The technology planner can profit from identifying possible impact vectors. Knowing what is possible, and assessing what is relatively likely, can lead to better plans.

The alternative to forecasting is to cover one's eyes and jump into the future unguided. It is far better to “look before you leap,” even if future vision is considerably less than 20/20. Technology managers need to understand likely patterns of acceptance and resistance to a changing technology, and how opportunities and challenges may arise, and include their implications in planning.

While the problems are both complex and potentially devastating, they also can offer opportunities for managers in their technology planning. This demands awareness of the methods used to forecast and analyze technologies and their impacts; these issues are discussed in the chapters to follow.

1.3.4 The Role of Social Forecasting

Technology managers quickly learn that social and political forces can dramatically affect patterns of technological change. Therefore, looking ahead must include social as well as technology and economic forecasts. This may seem a somewhat arbitrary distinction since both technology and the economy are elements of the social context; however, the division is convenient because forecasting sociopolitical factors involves different concepts and problems than projecting either technological or economic ones. Social forecasts often deal with deference values, such as respect and power, rather than with welfare values, such as income, wealth, or well-being. Ascher (1978) identified five issues that make these factors more volatile and therefore more difficult to forecast:

1. The factors often can be easily altered through human volition since material resources frequently are only marginally important.
2. There is seldom a consensus on a preferred direction of sociopolitical change.
3. Social attitudes are far less cumulative than material growth patterns.
4. Single discrete events are often the central focus.
5. A single factor is apt to be meaningless without reference to the entire sociopolitical context.

These issues make it difficult to assess the validity of sociopolitical forecasts. Since some approaches to social forecasting can be very expensive, this question of validity can limit their attractiveness to managers. However, making no social forecasting effort can be equivalent to assuming no changes in the status quo, and there is a lot of evidence that this can be even more expensive. For example, the predicted and validated aging of populations in developed countries is bound to have significant economic and political impacts that managers would be foolish to ignore. Therefore, a prudent manager should look for cost-effective methods of social forecasting and interpret results in light of their limitations.

Sociopolitical forecasts are likely to rely heavily on qualitative approaches. Exceptions include social indicator and demographic projections, regression analyses, and certain simulations. Indeed, even simulation models that produce quantitative output rely on quantifying qualitative input about the interaction of important variables. Ascher (1978) suggested that two sociopolitical forecasting techniques had special promise: scenarios and social indicator projections. To these should be added expert opinion and, in some contexts, simulation models. While these techniques appear to be the most promising, no method is without problems or limitations.

1.4 Conclusions

While it may be interesting, educational, and fun to explore the future of technologies for the sake of the knowledge itself, applying the methods presented in this book requires resources. The use of those resources must be justified by the value the forecast produces for the organization. That value will come from better decisions, even though those decisions occur in an environment laden with risks and uncertainties. The test of the validity of forecasting only really comes with the passage of time. Yet, decisions need to be made in the present, and delaying them can also generate significant, even disastrous, costs.

Experience with the methods described in this book shows that better decisions can result when careful consideration of the future and its uncertainties is included in making and implementing decisions. Therefore, those who make decisions about the future of technologies must balance the desire for more and better information about the future with their limited resources and inevitable time constraints. If this book succeeds in producing better strategies and tactics, ones that have benefited from an informed look into the future that expands knowledge and reduces uncertainty, then its outcomes will have been worthwhile.

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Chapter 2
Technology Forecasting

Chapter Summary: Chapter 1 sketched the roles that planning and forecasting play in improving decision making in organizations dealing with significant change. This chapter deals with technology forecasting in more depth. Models of technological growth and diffusion are introduced, and the methodological foundations, including the technology delivery system, are established. A range of related concepts in technology forecasting and impact assessment are introduced. The chapter ends with an overview of forecasting methods and some guidance in selecting among them.

2.1 What Is Technology Forecasting?

In this text, the definition of technology forecasting is broader than intuition might suggest. *Technology* is defined as systematized knowledge applied to alter, control, or order elements of the physical or social environments. This includes not only the hardware systems usually equated with technology, but systems of analysis, regulation, and management as well.

People have been adapting to fairly rapid technological changes for a long time. Managers in the latter stages of their careers have seen computer and information technology dramatically change the way they work and live. Their grandfathers may have been born in the era of horse-drawn transportation and steam locomotion and yet lived to see astronauts walk on the moon. However, despite the evidence of technology change and its impacts, organizations and individuals have not learned very much about how to anticipate and plan for it.

Technology forecasting is focused on changes in technology, such as its functional capacity, timing, or significance. It is distinct from forecasts in which technology plays a role but is not the central issue, such as population projections Ascher (1978). Forecasting of any kind is difficult or weather forecasting would be a lot more accurate. Meteorologists at least have data from years of observing weather patterns to help them. Technology forecasters deal with new concepts, with little historical evidence to draw upon. Like weather forecasting, the context of technology forecasting is very complex.

Technology forecasting activities masquerade under many names. This book adopts a broad definition that incorporates competitive technical intelligence, foresight, impact assessment, risk assessment, and technology road mapping. These approaches all adopt a systematic view for analyzing sociotechnical systems and draw upon a common set of methods. All are intended to aid in sound decision making. They differ in their intended audience, problem conceptualization, and mode of providing guidance.

- *Competitive technical intelligence* (CTI) emphasizes corporate or private sector applications. Analysis of open-source or “gray” literature frequently is central, and there is often a focus on numerical analyses and trends. CTI may emphasize downstream technologies that have reached the marketplace.
- *Foresight* often is adapted to public sector and governmental concerns. It emphasizes achieving desirable futures through policy implementation rather than accepting the future as a given. Foresight activities

may emphasize upstream or fundamental aspects of new technology.

- *Impact assessments* are a class of studies that evaluate the environmental and social effects of a technology. Environmental impact assessment (EIA) began in response to the requirements of the U.S. National Environmental Policy Act of 1969 (NEPA). Since then, it has spread throughout the world and its concerns have grown beyond the physical environment. Social impact assessment (SIA) emphasizes impacts on people, cultures, and institutions. It has been applied to concerns as wide-ranging as the effects of modern technology on indigenous peoples and the effects of texting on highway safety. Technology assessments (TAs) are broad-spectrum attempts to foresee all impacts of a new technology.
- *Risk assessment* addresses the probability of bad results ensuing from a technological decision. While it probably has been applied most often to technologies related to food and drugs and to the financial prospects for new ventures, it has been used to evaluate many other public health and safety concerns as well. These issues are complex and often involve subjective judgments as much as objective measures of probability.
- *Road mapping* emphasizes techniques for coordinating complex technologies distributed across multiple stakeholders or components of an organization. It frequently relies heavily on visual approaches. Clear alignment and consensus about priorities are often quick benefits of such studies.

Whatever the name, there are misunderstandings about sound technology forecasting, often fostered by past inadequate forecasting efforts.

Technological forecasting is not deterministic, that is, it does not seek to project a single certain future. Rather, good forecasts project a range of possible futures, of which some may be more likely than others. A good technology forecast may be quantitative, qualitative, or, frequently, a mixture of both. Since forecasts are done to help decision makers choose from a range of desirable futures, or to avoid the least desirable ones, it definitely has a normative component. The claim that technology forecasting has paid too little attention to the social aspects of new technology contains an element of truth. Thus, this book gives extensive emphasis to the social context of a technology and ways to include social concerns in the forecasting process.

To forecast technology, one must understand what is known about how technologies develop and mature. The growth of technologies is strongly affected by changes in the social/political context in which they are embedded and by the growth of supporting and competing technologies. Not only is this context dynamic, it affects different technologies in different ways. Thus, there is no single growth pattern that describes the development and diffusion of all technologies. There are general concepts of how technologies develop, however, and these useful guides are described in the following section

2.1.1 Models of Technology Growth and Diffusion

The attributes of technology most often forecast are:

1. Growth in functional capability
2. Rate of replacement of an old technology by a newer one
3. Market penetration
4. Diffusion

5. Likelihood and timing of technological breakthroughs

Regardless of the attribute to be forecast, it is important to understand both the technology and the process of conception, emergence, and diffusion that characterizes its growth. Measures of functional capacity may differ for technologies that appear similar. For example, maximum speed is one legitimate measure of fighter aircraft performance because of its mission. However, speed alone is not a legitimate measure for transport aircraft because it captures only part of the aircraft's functional capacity: to rapidly deliver a payload. Often the forecaster must understand not only the technology in question, but also earlier ones that fulfilled the same need. Such understanding is required to develop trends that are defined by successive technological approaches. A firm understanding of basic principles also is required to identify competitive technologies, as well as technologies that are necessary to support the subject technology or that may be supported by it.

Technologies generally follow a growth pattern that is S-shaped, as shown Figure 2.1. When the technology is *emerging,* growth is slow as innovators develop prototypes and try to determine the configuration of the product based upon the technology's functionality. Once the product is established, there is a period of *rapid growth*, followed by an inflection point and slower growth as the product enters a period of *maturity*. Eventually, the technology becomes obsolete and its use *declines*. This growth model is discussed further in Chapter 6.