A MANAGER'S GUIDE TO TECHNOLOGY FORECASTING AND STRATEGY ANALYSIS METHODS

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BATTELLE PRESS
Columbus • Richland

Library of Congress Cataloging-in-Publication Data

Millett, Stephen M., 1947–
A manager's guide to technology forecasting and strategy analysis methods/by Stephen M. Millett and Edward J. Honton.

p. cm.
Includes bibliographical references.
ISBN 0-935470-63-8 : $19.95
1. Technological forecasting. I. Honton, Edward J. 1955–
II. Title.
T174.M55 1991
658.4'0355—dc20 91-13690
CIP

Printed in the United States of America.

Battelle Press
505 King Avenue
Columbus, Ohio 43201-2693
614-424-6393
Toll Free: 1-800-451-3543
Fax: 614-424-5263

FOREWORD

Corporate managers, planners, and analysts ask many questions about technology forecasting and planning methods. Which forecasting method is most used today? What method is being used by which companies? How accurate are the methods? Unfortunately, there are no simple answers to these questions.

We think these questions reflect the confusion and misunderstanding that exist in many companies about technology forecasting and strategy analysis. Certainly forecasting and strategic business planning are a significant part of technology management. Yet the tools for managing technology as a corporate resource are not as well refined and understood as the tools for financial management or even those for personnel development.

Based on our experiences in workshops, conferences, projects, and consulting over the last decade, we have been sharing the following observations in response to the above questions:

1 No technology forecaster or analyst relies on just one, or even a few methods. Companies use many methods depending upon the subject, the goal, and available resources.

2 The variations in methods, techniques, and applications typically reflect the topic of analysis and the corporate culture more than the state of the art of the methods.

3 There appears to be a growing gap between decision-making

managers and information-producing analysts. Managers need answers, even if only approximations, quickly and in a manager-friendly manner as inputs to their decision-making process.

In this guide, we assess the current state of the art of 20 different forecasting methods, evaluate their advantages and disadvantages, suggest applications, and predict their future into the 1990s. Because we emphasize the merits and utility of the methods more than their mechanics, we clustered the methods into three broad categories:

1 **Trend Analyses**

2 **Expert Judgment**

3 **Multi-Option Analyses.**

We offer the following generalizations based upon this assessment:

1 **Too much emphasis has been placed on the accuracy of forecasts** and not enough on the educational and communication value of the forecasting process.

2 **Goals and purposes for the forecasts must be identified** before selecting the appropriate methods to achieve them. The very first question is "What is the question?" The second question is "What do you intend to do with the answer?" Then the methods are selected and applied accordingly.

3 **Methods should be used in combinations**. No one method can answer all questions. Trend analyses, expert judgment, and multi-option analyses can be combined according to the needs of the forecasting effort. How these methods are combined is very much dependent upon the skills of the analysts and managers and upon the corporate climate.

4 **Technology forecasting methods also need to grow** to incorporate applicable features of economic forecasting, political analysis, and market research. In the broadest sense, technologies, and especially their final products, are profoundly affected by nontechnical factors (such as economics, politics, public policy and regulation, social preferences, etc.).

5 **Technology forecasting and strategy analysis ideally should accomplish three goals:** first, provide a forecast of the future technological environment; second, suggest alternative technology strategies to managers; and third, evaluate these strategies to see which will produce the desired results.

6 **Nearly all the methods of technology forecasting and strategy analysis** that we examine **are also used for forecasting purposes outside technology.** The only methods that come close to being unique to technology are S-curves and patent trend analysis.

7 **We have observed recent growth in the number of specialists** within companies assigned to perform the specific job of technology forecasting.

We make some forecasts for the 1990s:

1 **Technology forecasting and strategy analysis methods will become better understood** and applied through their use in the corporate environment. The methods will become more sophisticated.

2 **More methods will be combined with each other.** All three categories of methods examined in this report show strong potential for improvement when used with other methods.

3 **The following methods will increase in popularity:**
trend extrapolation
time series estimation
regression analysis
historical analogies
patent trend analysis
scientific literature analysis
analysis of user created databases
interviews
questionnaires
idea generation
nominal group technique
scenarios
simulations.

4 **The following methods will decline in popularity:**
econometrics
systems dynamics
S-curves
input-output matrices
Delphi method
paths and trees
portfolio analysis.

5 **We are aware of only one new forecasting and strategy analysis method** that will emerge as newly popular in the 1990s, namely the creation of a user's own database for electronic analysis. There may be other newcomers of which we are not aware. However, such new tools are highly unlikely to replace the more then twenty methods considered in this guide within the next decade.

We conclude with several recommendations for managers. In general we believe managers need to

1 **Clarify their needs to analysts** so that they can be more responsive to managers' needs for decision making.

2 **Prepare a written inventory of existing tools and databases** presently used by the company. Analyze the inventory to ascertain whether a transfer of existing knowledge, software, or data from one working group to another would be beneficial.

3 **Examine the trends for the 1990s** in forecasting tools **and explore what these trends mean** for the company. Does changing software or data availability suggest any changes the company should make in the use of tools?

4 Request that analysts **evaluate any specific tools or databases** mentioned in this report **that promise to improve the company's forecasting ability** or provide a better understanding of technology problems.

5 **Implement the use of multiple methods in various combinations** for better technology forecasting. While there are a great number of possible combinations of methods, one array seems to be particularly attractive:

A Expert judgment (particularly interviews and surveys) to frame the right question for the forecasting study;

B Expert judgment (particularly idea generation and the nominal group technique, or variations thereof) to identify issues, factors, trends, variables, etc. to be included in the scope of the forecasting study;

C Trend analyses (particularly trend extrapolation, time series, and patent trend analysis) to understand thoroughly the past, present, and most feasible future of each factor in the scope of the forecast;

D Multi-option analysis (particularly scenarios and simulations) to integrate the trends and to generate alternative, including normative, views of the future;

E Expert judgment (particularly idea generation and the nominal group technique) to draw business implications and strategic options from the forecasts; and

F Trend analyses (particularly trend extrapolation and time series) combined with other forecasting methods (especially econometrics and financial projections) to do detailed, microscopic analysis for planning purposes.

6 **Expand their concept of technology forecasting toward** the broader concept of **product forecasting**, which includes business environment and corporate concerns as well as technological performance.

7 Incrementally **integrate changes required by the new technology forecasting methods** into the office. This includes acquiring appropriate computer hardware and software, ensuring adequate access to the proliferating number of electronic databases, and training staff to use both new forecasting tools and combinations of tools.

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CHAPTER 1

INTRODUCTION

Many companies now realize that technologies, especially intellectual properties in the forms of copyrights, patents, and licenses, are corporate assets that must be managed like money, facilities, and people. A significant part of technology management is forecasting and strategic business planning. Yet the tools for technology planning are not well refined or understood. Because of the number and type of questions asked about technology forecasting, we prepared this guide to clarify certain issues about forecasting and analytical methods so that managers can better appreciate and use the excellent work of many skilled analysts.

The information contained in this guide came from many sources. We collected and reviewed articles, papers, and books on the topics of forecasting, business strategy, and R&D management (a few of which we authored ourselves). We also drew upon dozens of our forecasting experiences for corporate clients in the United States, Europe, and Japan. We carefully used the confidential remarks of strategic planners and managers from hundreds of companies with whom we have formed friendships from our workshops and field visits. We have enjoyed direct contact with business people in the United States, Canada, Mexico, the United Kingdom, Ireland, the Netherlands, France, Portugal, Italy, Switzerland, Germany, Norway, Finland, Japan, and Korea. We have provided technical consultation to a wide variety of companies, including oil, electric, and

gas; automobile; telecommunication; aerospace and defense; postal service; consumer products; medical equipment; and health care, as well as governmental development agencies. Ultimately, this guide is the culmination of our ten years of Battelle work in the area of forecasting, strategy-making, and R&D management.

This guide is organized into three principal chapters: (1) **Trend Analyses** (including trend extrapolation, time series, regression analysis, systems dynamics, S-curves, analogies, and patent trend analysis); (2) **Expert Judgment** (including interviews, surveys, Delphi method, idea generation, and the nominal group technique); and, (3) **Multi-Option Analyses** (scenarios, simulations, paths and trees, and portfolio analysis). A conclusion follows with generalizations and our own expert judgment about developments toward the year 2000.

Before beginning our review of the methods, we need to discuss briefly two themes common to all of the above forecasting and strategy analysis methods. First, we need to define "technology forecasting" because there is confusion about what it is and is not, as compared with economic forecasting or weather forecasting. Second, we need to establish the context for technology forecasting by examining the stages of technological development common to many corporations.

Professor Martino in his popular textbook, *Technology Forecasting for Decision-Making,* defines technology forecasting as "prediction of the future characteristics of useful machines, procedures, or techniques." The accent is upon practical applications, not on scientific knowledge. It is also upon the characteristics, or parameters, of practical performance, not upon the actual appearance of the technology. Technology forecasting is not the same as product or market forecasting, although they are often confused. Managers typically think like customers: what is the product, what does it do, and what is its value? They often expect technology forecasts to address these questions, and they are disappointed when the forecasts do not. On the other hand, engineers often confuse technology with products and make claims that are difficult to support with the tools of technology forecasting alone.

William Ascher in his acclaimed book, *Forecasting. An Appraisal for Policy-Makers and Planners,* defines technology forecasting as the effort "to project technological capabilities and to predict the invention and spread of technological innovation. . ." He agrees with Martino that the subject is technological capabilities, but he differs on other aspects of the definition. Indeed, Ascher goes

further than either Martino or we would wish to go in defining technology forecasting.

What, after all, is meant by "forecasting"? In a narrow sense, the word means prediction (which Martino uses); and quantitative analysts think of prediction as a specific number. In a broad sense, however, forecasting is the expectation and estimation of future conditions typically bounded by ranges or described in words. Shell International, for example, likes to call what it does "foretelling" rather than "forecasting," precisely because Shell has yielded the broad definition of the term "forecasting" to the narrow definition of quantitative analysts. We still hold to the broad definition.

Therefore, we define technology forecasting as the process and result of thinking about the future, whether expressed in numbers or in words, of capabilities and applications of machines, physical processes, and applied science. Technology forecasting certainly involves more than projection, and it does not have to be so specific as a prediction. It does not have to describe the actual invention and spread of technology; but if it can, it would make the forecast more comprehensive and useful to managers. One of the challenges of the 1990s is to stretch forecasting methods further beyond the domain of technology and to integrate them with other types of forecasting methods, such as those used in economics, politics, and meteorology.

Indeed, in the corporate context that we have in mind, "product forecasting" may be more descriptive of what we are really attempting than "technology forecasting." This new term opens up horizons for integrating technologies with nontechnical considerations in a comprehensive package that would be more useful to managers.

We completely agree with Martino that technology forecasts should include four elements:

1 a specified time period (such as five or ten years from now or dates such as 1992, 2000, 2010, etc.)

2 the technology domain (mechanics, approach, and topology in general terms, at least)

3 performance characteristics of the technology, especially the parameters (defined and described, if not specified in numbers)

4 likelihood or probability of occurrence by the specified time.

We further agree with Martino that accuracy is not the sole, or even major, emphasis of technology forecasting. Our experience has been consistent with his in that the value of a forecast is measured by its usefulness to a manager faced with a decision. Both managers and analysts have overstressed the importance of accuracy by believing and acting upon forecasted numbers. A major shortcoming of too many forecasting tools is that they produce answers without explanations, and managers compound the problem by accepting numbers without further discussion. Astute managers question vigorously the methods, results, and business implications of forecasts. As forecasters and analysts ourselves, we want greater accuracy; but we realize that accuracy is not the only benefit of forecasts, and that inaccurate forecasts can produce positive benefits. Beyond accuracy, the timeliness and packaging of the forecast are extremely important to managers.

Forecasting is usually performed along with planning. Unfortunately, much corporate planning is as stilted as forecasting. We even hate to use the word "planning" because too many business people associate it with boring meetings, lengthy reports, and soon-forgotten distractions to the day-to-day business of making money. Planning was never meant to become a substitute for thinking, but too often in practice it has. Today, corporations need more "strategic thinking" and less so-called "strategic planning." We prefer to use the term "technology forecasting and strategy analysis methods" to mean ways of thinking about future technological progress and new product development with respect to both external business environments and internal corporate cultures. The goal is to evaluate and select the corporate strategies for actions that are most likely to produce desired results. Ultimately forecasters and analysts present their conclusions and managers take action.

Several authors have presented models of the R&D process in terms of discreet stages of technological development. Because an overview of the innovation process does provide a practical context for technology forecasting methods, we would like to present our own model of the process:

1 **Early theorizing and conceptualization.** This is the "light bulb" phase when someone comes up with an intuitive bright idea. The idea at this stage has little form and substance, but much enthusiasm.

2 **Exploratory research.** Will the idea work? What form will it take? At this stage the researchers need to achieve some

critical parameters. Scientific methods, plus a lot of trial and error, are used to manifest the early idea, which is often modified in the process.

3 **Component development.** If the second stage produces promising results, the next stage is to develop and fabricate the parts that will make the emerging technology work.

4 **Prototype development.** If the third stage succeeds in its goals, the components will be assembled into the prototype product.

5 **Testing of prototype.** This may involve both physical testing of the assembled technology and market testing for possible consumer demand.

6 **Initial manufacturing and marketing of the product.**

7 **Consumer acceptance or rejection.**

8 **Product modification and improvements.**

9 **Product maturity and decline.**

Technology forecasting and strategy analysis methods can be employed at virtually any one of these stages, but they may have different applications. In the first three stages, the forecast is most likely to conform to the strict definition of technology forecasting. At the later stages, forecasts and analyses more likely take the shape of product, market, and economic forecasts. By Stage 7 we are strictly faced with product forecasts rather than technology forecasts. The manager needs to appreciate the stage of technological innovation in which the forecast is conducted. The analyst also needs to understand this context for the forecast and appreciate the decision needs of the manager who will be using the forecast.

One challenge for analysts and managers in the 1990s will be to explore innovative ways of combining and applying the methods of technology forecasting. Another challenge will be to integrate technology forecasting with market research methods. Market research methods are not covered in this study, although we believe that exploration in this direction by technologists is indeed merited to achieve the full potential of "product forecasting." Our unrefined impression is that generally the methods of market research are similar to those of technology forecasting, especially the variations

on expert judgment techniques, including surveys, interviews, and focus groups. Sales projections also strike us as being essentially trend projections combined with expert judgment. In market research, more than in technology forecasting, the "experts" in "expert judgment" are the target customers themselves, not the R&D technologists. Technology forecasters and market researchers have a lot to learn from each other.

We are very pleased to see a new appreciation for expert judgment methods. The July–September 1990 special issue of the *Journal of Forecasting* focused on expert judgment methods. The editors acknowledged that "Together, these papers question the assumption that statistically based forecasting is superior to forecasts made by the exercise of human judgment. . . Five years ago we could not have foreseen that the role of judgment in forecasting would play such a significant role as it does now, but some things are difficult to forecast!" Indeed, on some matters, analysts have more difficulty preparing forecasts than managers have in using them, because managers have long appreciated the importance of expert judgment in making decisions about today's investments and tomorrow's returns.