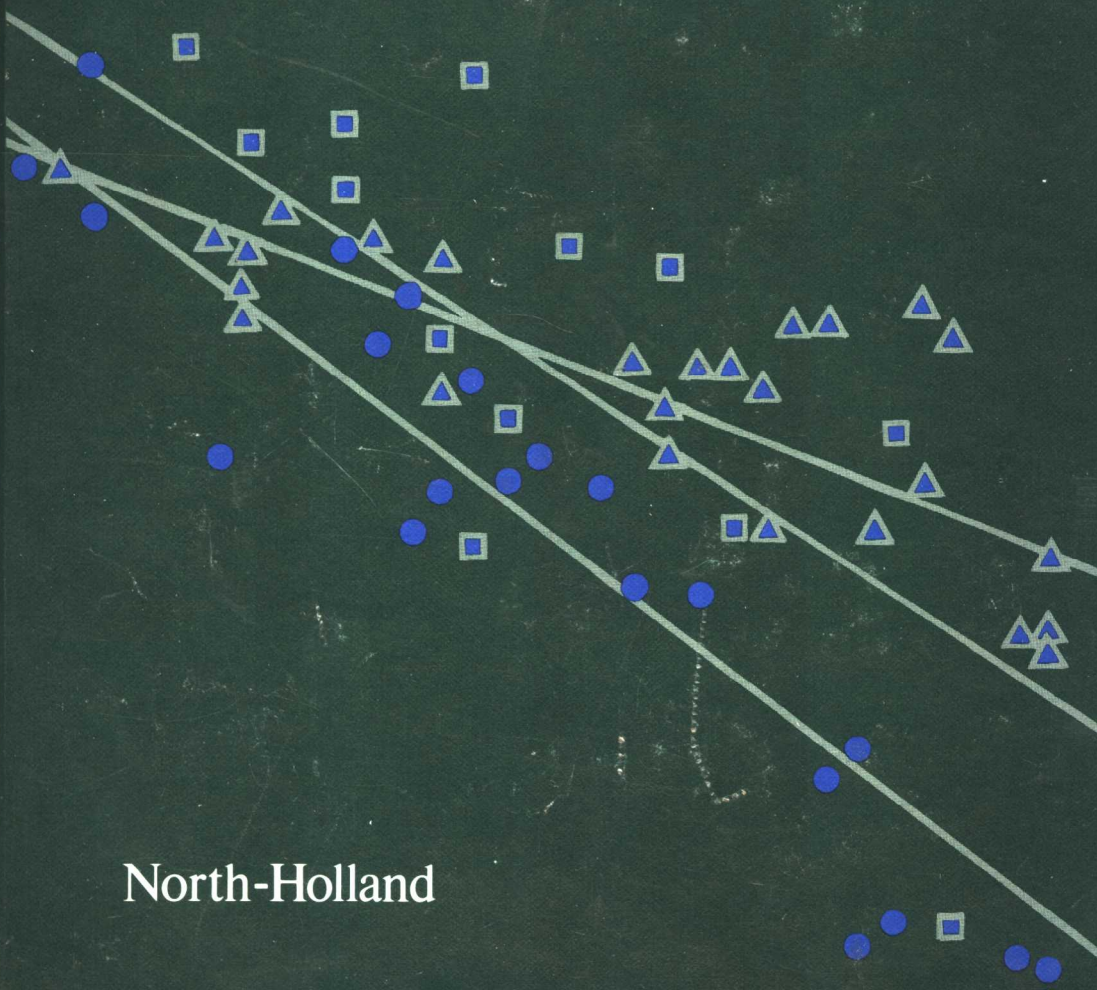
Technological Forecasting for Decision Making

Second Edition

Joseph P. Martino



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This book is dedicated to
my wife, Mary,
whose constant encouragement
and support made it possible.

Preface to the Second Edition

Since the first edition of this book there have been significant changes in the state of the art of technological forecasting. These include refinements and improvements on older techniques, as well as some completely new techniques. In addition, there has been a change in emphasis among techniques; for instance, a decade ago computer models were hardly used, whereas their use is now widespread. This new edition brings together the new techniques and the changed emphases and integrates them with the older techniques.

Another important change since the first edition is the increased use of technological forecasting for a variety of applications. It has become widely accepted in industry, government, and universities, and the chapters on applications have been updated to reflect this.

Finally, this second edition has benefited from considerable feedback from users, both individual readers and those who have used it as a text in formal classes. Some of the background material and historical illustrations have been shortened or eliminated to sharpen the focus on the more important points. In addition, lengthy derivations have been omitted where they did not contribute to an understanding of the techniques presented. Readers can refer to the original literature to find these derivations, and those interested only in applications of techniques will find them presented more compactly here.

Joseph P. Martino

Preface to the First Edition

This book is intended to provide an advanced treatment of technological forecasting. While no prior acquaintance with the subject is assumed, the treatment does assume a fairly strong background in one of the sciences or one of the engineering disciplines, and its presentation some prior knowledge of calculus. Some knowledge of statistics is also desirable, but a statistical appendix is provided for those with no prior acquaintance with the discipline.

This is a "how to" book: how to do technological forecasting, how to apply it in specific decision situations, and how to avoid some of the more common errors and difficulties in the preparation of individual forecasts. It is written primarily for those—graduates and undergraduates—who wish to become technological forecasters. It is also intended for professional technological forecasters who wish to know more about the subject. In addition, the book is intended for those practicing scientists and engineers who wish to know more about technological forecasting, for administrators, in the scientific and engineering fields, and for other decision makers whose work is heavily influenced by technological change.

For the student of forecasting as well as the professional forecaster, the book presents a detailed discussion of all the important techniques currently in use. For each technique, the discussion includes the rationale behind it, a description of the methodology including mathematical derivations where these are appropriate, and one or more historical examples. In addition, the proper conditions for application of each technique are described, and the strengths and weaknesses of each technique discussed. Each chapter concludes with several problems intended to give the user an opportunity to practice the methods covered therein.

For the practicing scientist or engineer, the book provides information he will need to understand technological forecasting. There are three

reasons why he will need such understanding. First, more and more scientists and engineers are going to be called upon to participate in the making of forecasts in the areas in which they are well informed. They should understand the methods that will be used by the professional forecasters with whom they will be required to collaborate. Second, technological forecasting will be increasingly used in the planning of scientific and technological activity. It is advantageous for them, therefore, to understand the bases upon which decisions will be made about their work. Third, technological forecasting can be of value in expanding the application of their work. Since most scientists and engineers are interested in seeing their work applied, technological forecasts can be of direct benefit to them. Regardless of which of these reasons is of most importance in a specific case, the practicing scientist or engineer will find the information in this book to be of value in both making and using forecasts.

Administrators in science and engineering and other decision makers whose work will be influenced by technological change will not usually be making detailed technological forecasts. Forecasts will be prepared for them by technical specialists and professional forecasters. Nevertheless, it is important for these decision makers to be aware of the methods commonly used, to know when these methods are appropriate and when they are not, and particularly to know the strengths and weaknesses of the various methods. This book can provide them with adequate background to make fully effective use of the forecasts they will receive.

The material in the book is divided into three parts. The first part contains a discussion of forecasting methods; the second describes applications of technological forecasting to various types of decisions; the third provides instruction and guidance for the preparation and presentation of specific forecasts to be utilized in specific decisions. The student of forecasting and the professional forecaster will find the first and third parts most useful; they will draw on the second part as the occasion demands. Other users will probably make most frequent use of the second part; they will perhaps consult the first and third parts for specific information about forecasting methods or for evaluating forecasts they have been given.

This book differs from most others on the subject in two respects. First, it maintains continuity and orderly growth of the subject; the material is presented in sequence of increasing difficulty and increasing rigor. Second, it stresses the viewpoint that technological forecasts are not made for their own sake but as inputs to decisions. The book emphasizes that technological forecasting is an important element in the decision making process. However, the distinction between the role of the forecaster who *advises* a decision maker and that of the decision maker himself is repeatedly emphasized.

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Contents

Chapter 1

Introduction

1. What Is Technological Forecasting?

This book is about technological forecasting: How to do it, how to apply it in specific situations, and how to prepare forecasts so that they can be useful from the decision-making standpoint.

Before discussing technological forecasting we must first define *technology*. *Webster's Seventh Collegiate Dictionary* defines it as "the totality of the means employed to provide objects necessary for human sustenance and comfort." This definition is adequate for our purposes, provided that we understand *objects* to include not only goods but services. Thus technology here will mean the tools, techniques, and procedures used to accomplish some desired human purpose; that is, technology is not restricted to hardware only but may include "know-how" and "software."

The term *technology* is frequently used in the narrower sense of applied science or the use of science-based knowledge. In actuality, however, most of the technology in the world is not science-based; it is largely empirical in nature. Before the growth of science in the 17th century virtually all technology was empirical rather than based on scientific theories.

There is no intent here to disparage science nor its use in the advancement of technology; instead, the point is simply to recognize that much of technology is still based on practical experience and not on scientific theory. Even this purely empirical technology, however, is the province of the technological forecaster. Thus we are concerned not solely with science-based technology but with all means used to provide the tools, techniques, and procedures necessary for human sustenance and comfort.

Webster defines *forecast* as "to calculate or predict (some future event or condition) usually as a result of rational study and analysis of available pertinent data." The idea here is to state what is going to occur.

Combining the ideas of technology and forecasting, then, we define a technological forecast as "a prediction of the future characteristics of useful machines, procedures, or techniques."

There are two important points contained in this definition. First, a technological forecast deals with characteristics, such as levels of performance (e.g., speed, power, temperature). It does not have to state how these characteristics will be achieved. That is, the forecaster is not required to invent the technology being forecast. Even though the forecaster may predict characteristics that exceed the limitations of current technical approaches, the forecast need not state how these will be achieved. The forecaster's obligation is fulfilled by warning that these limitations will be surpassed.

Second, technological forecasting deals with useful machines, procedures, or techniques. In particular, this is intended to exclude from the domain of technological forecasting those items intended for luxury or amusement, which depend more on popular tastes than on technological capability. It does not seem possible to predict these rationally; however, the forecaster might be concerned with the means by which popular tastes will be formed, such as advertising or propaganda.

Having defined technological forecasting in a general sense, we now want to characterize it more precisely. A technological forecast (just as any good forecast) has four elements: the time of the forecast, the technology being forecast, a statement of the characteristics of the technology, and a statement of the probability associated with the forecast. What are these individual elements?

The time of the forecast is the future date when the forecast is to be realized. This may be a single point in time or a time span. In either case the time of the forecast should be stated clearly.

The technology being forecast may be stated in either of two ways, depending upon the intent and nature of the forecast; but before specifying this further, we need to define two terms.

The first term is *technical approach*. This means a specific technical means of solving a problem or performing a particular function. For instance, piston engines and jet engines are two different technical approaches to the general function of powering aircraft; incandescent lamps and fluorescent lamps are two different technical approaches to the function of providing illumination. Sometimes a technical approach can be further subdivided. Jet engines can be divided into turbojets and turbofans. For some purposes the forecaster will consider jet engines as a single technical approach; in other cases he will consider turbojets and turbofans as alternative technical approaches to the function of powering an aircraft.

The second term is *technology*. By this we mean a family or series of technical approaches that have some major characteristic in common, or

which perform the same function. For instance, when the forecaster wishes to distinguish between turbojets and turbofans as technical approaches, the entire class of jet engines is then a technology, to be distinguished from the technology of piston engines. When the forecaster wishes to distinguish between incandescent and fluorescent lamps, the entire class of electric lights is a technology, to be distinguished from other technologies such as gas lights. On the basis of context, this use of the word *technology* will be easily distinguished from the broader use defined above.

Armed with these definitions, we can be precise about the technology element of a technological forecast: The forecast must state whether it is for a single technical approach or for a more general technology. If it is for a technical approach, the forecast must be clear about how that approach is to be distinguished from other approaches in the same general technology; if it is for a technology, the forecast must be clear about how that technology is to be distinguished from others used for the same function.

The third element of the forecast, the characteristics of the technology, are given in terms of "functional capability." Technology is intended to perform some function, and functional capability is a quantitative measure of its ability to carry out this function. This definition is broader than simply the technical performance of a machine. For instance, a function to be performed is the transportation of people. One measure of the functional capability available is speed. (Clearly this is not the only such measure, and for some purposes not even the best.) Hence a means of transportation may have its functional capability measured in miles per hour. However, a specific device used to carry out this function may also have one or more technical measures of performance, such as miles per gallon of fuel or percentage of efficiency. These may be of interest to the technological forecaster only indirectly, as they bear on the functional capability, or they may be of direct concern (e.g., a forecast used in a R&D program to reduce the fuel consumption of an engine). The level of functional capability is a numerical measure of the functional capability available at any time; thus at any time the level of functional capability in "people moving" may be the actual speed in miles per hour of the devices used. The third element of a technological forecast, therefore, is a specification of the functional capability being forecast, and a numerical measure of its level.

The fourth element of the forecast is a probability, which may be stated in many ways: The forecast may give the probability of achieving a given level of functional capability at all, it may state the probability of achieving a given level by a certain time, or it may state the probability distribution over the levels that might be achieved by a specific time. When the probability is not stated, it is assumed to be 100%.