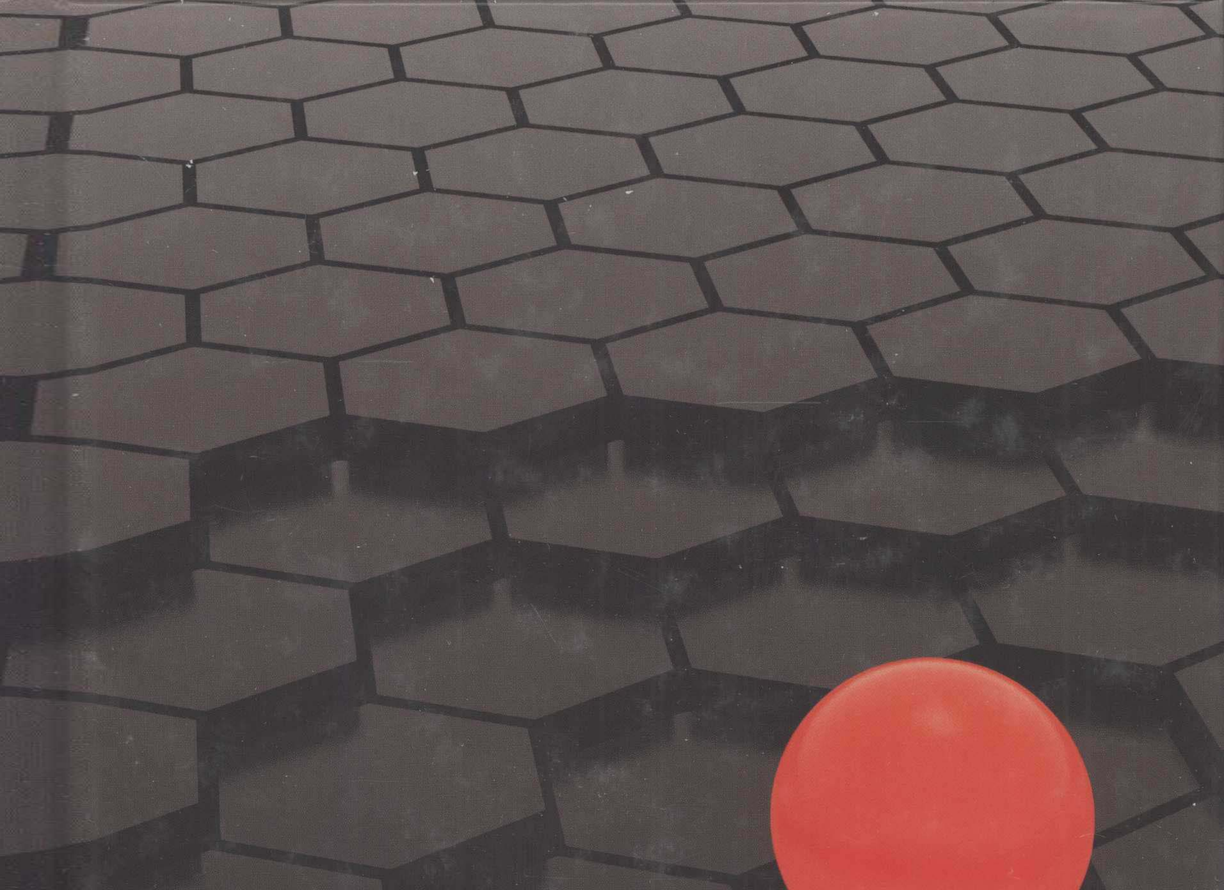

THIRD EDITION

managing technological innovation

Competitive Advantage from Change

FREDERICK BETZ

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MANAGING TECHNOLOGICAL INNOVATION

This book is dedicated to my wife, Nancy, and my children, Sara, Fred, and David.

PREFACE

INNOVATION PRACTICE

Our focus is on practicing successful innovation, which will be summarized, at the end, as a kind of guide to practice—a handbook of innovation. We will describe the theory for six practical management procedures in innovation:

1. How to manage innovation processes
2. How to manage research and development
3. How to manage product development
4. How to manage high-tech marketing
5. How to manage service innovation
6. How to manage biotechnology innovation

We will build toward these useful procedures—by examining the details of innovation theory—to summarize these procedures in chapter.

CASES AND THEORY

To get to practice, one must review theory in cases of actual practice. What is different about this book is that it not only tells stories—stories about technology and business—but it also deepens these stories with a *theory of innovation.* This is different because grounding theory in research has not often been a typical practice in the business literature. Instead, the usual literary style is to use case studies of *best practice*—what some company did at some time—in other words, a business process. This has been called the Harvard Business School *case method.*

But case studies by themselves may not develop or validate theory. They may be not of much practical use, because how something worked in one company is not a complete story. It does not necessarily tell why. And it is not only the "how" of companies doing something (a best practice) but the "why" of it working (or failing). The "why" can only be found in research on such cases of real practice—but relevant to theory. It is research-grounded theory that is useful. What worked for one company may or may not work for another company—nor even work for the same company in the future. We describe all cases in this book in a theoretical framework—cases relevant to theory and theory in the context of cases.

For example, a famous case of best practice in product innovation was the use of "concurrent engineering design," dramatically illustrated by the development of the Ford Taurus car in 1981. This development was extensively written about and studied in the business literature. Lew Veraldi, the Ford project leader wrote:

> **[T]he team sought out the best vehicles in the world and evaluated more than 400 characteristics on each of them to identity those vehicles that were the best in the world for particular items. These items ranged from door closing efforts, to the feel of the heater control, to the under-hood appearance. The cars identified included BMW, Mercedes, Toyota Cressida and Audi 5000. Once completed, the task of the Taurus Team was to implement design and/or processes that met or exceeded those "Best Objectives" (Veraldi 1988, 5).**

The Taurus car saved the Ford Motor Company from bankruptcy in the early 1980s. Yet in 2008, Ford terminated the model, as it had not sold well for years and Ford had allowed it to become technically obsolete. Why? Why had Ford not improved Taurus over the years? It could have used that best practice of "concurrent engineering design" to continually improve the car into a brand-recognized, quality product. And a competitive Taurus might have saved Ford from its near bankruptcy in 2007–2008, when Ford desperately needed a *brand-recognized* quality compact car—stylish, fuel efficient, high performance. It is the whys in the business world that constitute *theory.* Why is concurrent engineering design insufficient as a business process to maintain continual product improvement in a product and its technologies? This is one of many questions we address in our cases and theory of innovation.

Briefly, the "why" of the Taurus story is that subsequent CEOs at Ford were not committed to innovation as a competitive strategy, only to business acquisitions. After the success of Taurus in the 1980s, in the 1990s Ford bought other brands of cars, such as Volvo and Jaguar. But later in the 2000s, facing bankruptcy, Ford sold these brands off—after losing a great deal of money on them. In 2009, Jaguar, once a British car and then an American Ford car, became an Indian car. In 2010, Volvo, once a Swedish car and then an American Ford car, became a Chinese car. This is an example of a failure of proper innovation strategy—a lack of proper top-down and bottom-up technology implementation at Ford—and theory that we will discuss in Chapter 8, "Innovation and Strategy."

Grounded theory is what counts—both the how and why. Here we will use stories of real practice—some "best practice" and some "worst practice"—to ground innovation theory and/or raise challenges to theory—both the how and why of successful innovation.

THE FIELD OF ENGINEERING MANAGEMENT AND TECHNOLOGY

Technological innovation is a complicated story and theory, because it has both a business side and a technical side. The business side focuses on using technological progress to design, produce, and market new high-tech products/services/processes. The technical side focuses on inventing new technology and developing its performance sufficiently to embed in high-tech products/services/processes. Personnel with business educations normally perform the business side of innovation, whereas personnel with engineering or science or computer science or mathematics educations normally perform the technical side of innovation. As business processes can be complicated and managing them can be challenging, so, too, can technical processes be complicated, and managing them challenging.

The study of managing technical processes began with the field of *engineering management* (EM)—so named since engineers were predominantly the technical personnel who develop new products and production processes. However, as information technology expanded in the second half of the twentieth century, other kinds of technical personnel exceeded the numbers of engineers in a business, and these were personnel in the computer fields: programmers, computer scientists, mathematicians. So the field of engineering management was broadened to include all kinds of technical personnel involved in all kinds of technologies. Accordingly, the field was renamed management of engineering and technology—or *management of technology* (MOT), for short. The idea that is central to MOT is that technology strategy and business strategy should be integrated for technology to provide a competitive edge to business. MOT can be divided into two classifications:

1. Empirical—EM/MOT is *descriptive*, describing actual historical patterns of change in science, technology, and economy.
2. Theoretical—EM/MOT is also *prescriptive*, developing useful concepts, techniques, and tools for managing future change in science, technology, and economy.

For the first half of the twentieth century, technological progress was primarily driven by the invention and production of physical goods. But as the second half of twentieth century evolved, dramatic new progress in information technology and in molecular biology fostered economic progress in industries of information, services, and biotechnology. This third edition of this book continues to broaden innovation study on a proper breadth across all the kinds of technologies—material, power, biological, and informational technologies.

ORGANIZATION OF THE BOOK

The questions we will pose and answer include the following:

1. How is innovation organized as a process?
2. What is technology?

3. What kinds of technologies are there?
4. Why is progress in any technology eventually finite?
5. How does technological progress impact a nation?
6. How can innovation strategy be formulated for a nation?
7. How does technological progress impact a business?
8. How can a manager identify technologies relevant to the future of a business?
9. How should high-tech research and development projects be managed?
10. How should innovation strategy be formulated in a business?
11. How does the innovation differ in hardware, software, sciences, and biotechnology?
12. What is the ethical context of technology?

These questions cross both the technical and business aspects of a business system. Any business must be run as a *system*: a business system developing and designing products/services, producing products/services, and selling these into a market. The *technical functions* of a business system emphasize the "upstream part of the operations," doing the research and development of products and production. The *business functions* of a business system emphasize the "downstream part of the operations," doing the financial, sales, and marketing activities.

Accordingly, this book was written to cover the concepts that bridge and connect the technical and business aspects of a business system. The chapters of the text are so divided between the two sides:

1. Part I, Technology Competitiveness (Chapters 1 to 8), covers the business side of innovation.
2. Part II, Technology Strategy (Chapter 9 to 15), covers the technical side of innovation.

Part III is the Innovation Handbook, covered in Chapter 16 as Innovation Practice.

MBA AND EM/MOT DEGREES

The two aspects of business and technology provide different foci for graduate management programs—either in engineering schools (offering EM or MOT degrees) or in business schools offering MBA degrees. This book can be used to provide an overview of innovation in either kind of program.

For example, as sketched in Figure 0.1, Nguyen Hoang Chi Duc has compared the two approaches: (1) in an MBA program, focusing on the *business aspects* of a business system, or (2) in an EM/MOT program, focusing on the technical aspects of a business system (Nguyen 2010).

In any academic degree program, the study of processes in business should include both business and technical aspects. However, because of differing intellectual

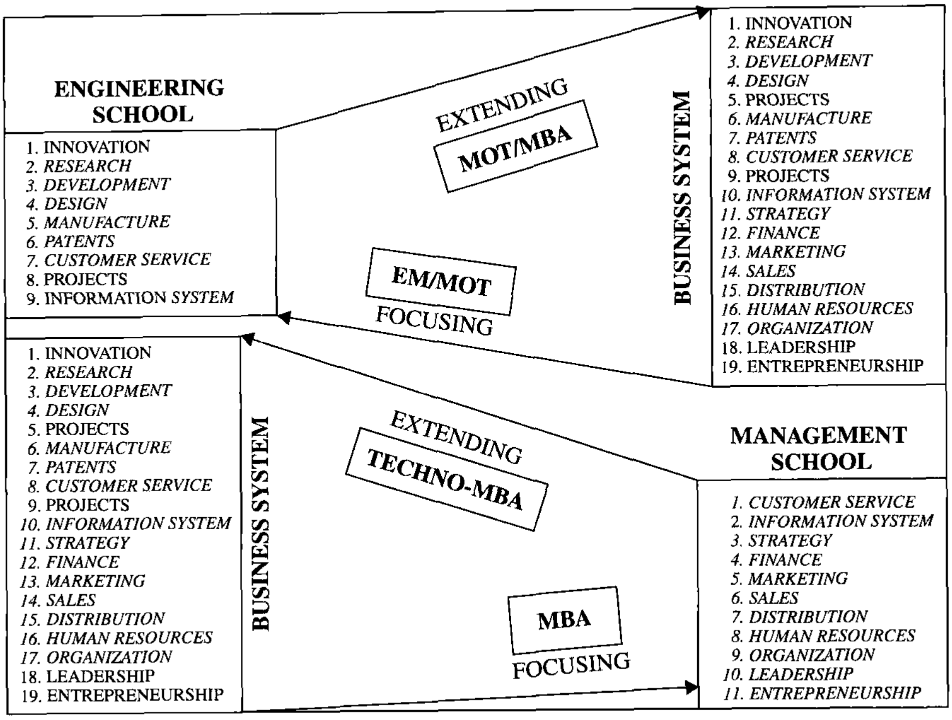

Figure 0.1 MBA and EM/MOT programs

priorities, MBA programs in business schools tend to emphasize the business aspects: customer service, information system, strategy, finance, marketing, sales, distribution, human resources, organization, leadership, entrepreneurship. Conversely, MOT/EM programs (in departments of industrial engineering or in engineering management) in engineering schools tend to emphasize the technical aspects: innovation, research, development, design, manufacture, patents, customer service, information system, strategy. The purpose of an overview course on innovation in either program is to assist in extending either program toward a more complete view of the business system (business + technical).

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FREDERICK BETZ

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III. INNOVATION HANDBOOK

I. TECHNOLOGY COMPETITIVENESS—BUSINESS BASE OF INNOVATION

1
TECHNOLOGICAL INNOVATION

INTRODUCTION

Technological innovation is, without doubt, the major force for change in modern society—a force of knowledge. There are two basic issues about knowledge: (1) creating knowledge and (2) applying knowledge. The first is the domain of science and the second is the domain of technology. This book focuses on the second domain, technology—the application of knowledge.

But there is a difference between technology and scientific technology. The world has had technology since the dawn of the Stone Age—when humanity's predecessors, the hominoids, chipped stones into tools. In fact, the history of humanity may be classified into ages of technologies—the Stone Age, the Bronze Age, the Iron Age. But what age shall we call our age, the modern age? As a reflection of its influence on society, a most descriptive term would be the age of science and technology. In historical fact, the transition from antiquity to modern arose from the origin of science and from thence all the technologies derived from science—scientific technology. Technologies are the "how" to do something; science is the "why" of something. So scientific technologies are both the how and why something can be done in nature. Science understands nature. Scientific technology manipulates nature. And this is good or bad—depending what we do to nature.

The basis for our modern age, characterized by so many new technologies and rapid technological progress, is the science base of modern technologies—scientific technology.

These are the modern connections—from science to technology to economy. Scientific technologies provide the basis for new high-tech products, services, and processes of modern economic development. The study of these connections is the focus of the topic of *technological innovation.* The field of management of technology (MOT) studies the principles of innovation, which describe the general patterns and principles in technological progress—the *theory of innovation.* As in any social theory, the *context* of the application of the theory affects the *generality and validity* of theory. So, too, with innovation theory, successful innovation is context dependent, and that theory needs to be illustrated and bounded by the contexts of actual historical examples of innovation. The first cases we will examine are the innovations of the Internet, Google, Xerography, and the Altos PC.

There is a "big picture" of innovation—science and technology and economy—and the historical industrialization of the world. There is also a "smaller picture" of innovation—businesses and competition and high-tech products/services. Innovation operates at two levels: macro and micro. We begin by looking at the macro level by asking the following questions:

- How does innovation create wealth?
- How does innovation transform scientific nature into economic utility?
- Who makes innovation?

TIMELINE OF SCIENCE, TECHNOLOGY, AND INDUSTRIALIZATION

Historically, the grand theme of innovation has been the invention of major new technologies and their dramatic impacts—changing all of a society and all societies. This story of the modern world has been both dramatic and ruthless. The drama has been the total transformation of societies in the world from feudal and tribal to industrial. The ruthlessness in technological change has been its force, which no society could resist and which has been called a *technology imperative.* Technological change has been irresistible—in military conflict, in business competition, and in societal transformations. (The latest of these imperatives is the globalization of the world, driven by the Internet. For example in 2010, the government of China decided that it would control Google in China or Google would have to leave China.)

Going back to the 1300s and 1400s in Europe, there were two technological innovations that provided the technical basis for the beginning of our modern era: the gun and the printing press. They were not scientific technologies, but only technologies; as scientific technologies were to begin later in the 1700s with the steam engine and the Bessemer steel process. The technologies of the gun and printing press had been *invented* in China, but were *innovated* in Europe. This is an important distinction between invention only and innovation as both invention and commercialization. The gun was improved and commercialized in Europe, and it was so potent a weapon that the gun ended the ancient dominance of the feudal warrior—a military technology imperative. In parallel, the improvement and commercialization of the printing press made books relatively inexpensive and fostered the secularization of knowledge. This combination of the rising societal dominance of a mercantile class (*capitalist*) and the deepening secularization of knowledge (*science*) are hallmarks of a modern society. After the fifteenth century, the political