Contents

Preface

The seventh edition of *Managing Engineering and Technology* maintains the focus of prior editions on supporting the growth of engineers into engineering managers, while considering the changing professions of engineering and engineering management. Engineers are talented problem solvers who often lack the training or expertise to solve problems through others. To build that expertise, *Managing Engineering and Technology* provides readers with the foundations of engineering management in five parts. In Part 1, we introduce the concept of engineering management, its relationship to engineering, and its historical underpinnings. In Part 2, we provide the core of management thought, including the four traditional roles of management—planning, organizing, leading, and controlling—with a particular focus on leadership and how leadership fits into an engineering management context. In addition, we provide tools to understand how human motivation and leadership are used to promote effectively working with and managing technical professionals. In Part 3, we explore both traditional (e.g., managing design) and non-traditional (e.g., managing marketing) roles of the engineering manager when managing technology. In Part 4, we provide an overview of the Project Management process. And in Part 5, we provide tools and discuss key topics needed to be successful in an engineering management career, including an exploration of engineering ethics, tools for career management, and key concepts of the forces changing the worlds of engineering and engineering management, including globalization.

WHAT'S NEW IN THIS EDITION?

This edition welcomes a new author with substantial experience as a practicing engineering manager and engineering management educator. That change brings a number of new and improved content to assist in the development of students' engineering management skills. The text is updated throughout, with new and revised content in each chapter. Key enhancements include:

- **New vignettes** in each chapter that explore modern developments in the management of engineering and technology with an application or example tied to the material from that chapter. These include discussions of highly successful engineering managers and those with headline grabbing ethical failings.
- **An entirely rewritten Chapter 13 on marketing**, with a focus on the movement toward digital marketing and how an engineering toolset can be used in this data-driven world.

- **Extensive new material in Chapter 16 on ethics**, with new ethical models incorporated that are typically easier for undergraduate students to relate to and utilize.
- **A substantially rewritten Chapter 18**, updated to reflect the current state of globalization and aspects of political unrest around the world.
- **Refreshed and updated content** in each chapter that highlights current trends and topics, such as the many roles of engineering in Amazon, Inc., updated leadership models, and examinations of leadership and management from beyond the Western world. In addition, changes to modernize the language and make it more welcoming and inclusive were made throughout the text. These updates included substantial streamlining of several chapters, reducing the overall text length by 10% while maintaining all key concepts and content.

FOR THE INSTRUCTOR

All of these considerable enhancements were made while retaining the same organization and topical flow from the sixth edition to allow for a smoother adoption for instructors. At the same time, this new material has led to considerable changes in the exercises for each chapter. Most chapters have 25%+ new questions from the prior edition. An updated instructor's guide and chapter slides are available at www.pearson.com/engineering-resources.

Acknowledgments

Together we'd like to thank Dan Babcock for his initial vision for this text and all of our colleagues at the American Society for Engineering Management and the American Society for Engineering Education who have helped clarify our thinking and writing about Engineering Management and Engineering Management education over the years. Those acknowledged in prior editions whose work continues to contribute to this edition include Henry Metzner (Missouri S&T), Jean Babcock, Ted Eschenbach (U. Alaska-Anchorage), Thomas A. Crosby (Pal's Sudden Service), Charles W. Keller (U. Kansas), Brian Goldiez (U. Central Florida), Nabeel Yousef (Daytona State College), and C. Steven Griffin (CSR).

Notable supporters for the thinking that went into this edition include Craig Downing (Rose-Hulman), Ted Eschenbach (U. Alaska-Anchorage), and Paul Kauffmann (East Carolina University). In addition, we thank our students who, over the years, have both intentionally and unwittingly helped us to identify opportunities to improve the text and areas of new knowledge that needed to be incorporated. For this edition we are extremely grateful to Norm Asbjornson of AAON, Inc. and Doug Melton of the Kern Entrepreneurial Engineering Network for use of their materials when developing the vignettes for Chapters 4 and 9, and to the team at Pearson for their guidance and support.

Most importantly, we thank our families for their continued support and encouragement. Without the love and patience of Jack Selter and Melanie, Ana, Megan, and William Griffin Schell the journey to create this text would not have been possible.

Part I

Introduction to Engineering Management

1

Engineering and Management

PREVIEW

Today's technological society is constantly changing, and with this change comes a need for the engineer to be able to address society's technological challenges as well as the opportunities for the future. Engineers play a key role in maintaining technological leadership and a sound economy as the world becomes flatter in today's global economy. To do this, the engineer needs to remain alert to changing products, processes, technologies, and opportunities. To make the transition from successful engineer to successful engineering manager, engineers must learn and apply a new set of tools.

To assist the engineer prepare for a productive life and position of leadership, this chapter begins with a discussion of the origins of engineering practice and education, the nature of the engineering profession, and the types of engineers, their work, and their employers. Next, management is defined and managerial jobs and functions are characterized. Finally, these topics are synthesized by defining engineering management and a discussion of the expectation of managerial responsibilities in an engineering career.

LEARNING OBJECTIVES

When you have finished studying this chapter, you should be able to do the following:

- Describe the origins of engineering practice.
- Identify the functions of management.
- Explain what engineering management is.
- Explain the need for engineers in management.

ENGINEERING

Origins of Engineering

The words *engineer* and *ingenious* both stem from the Latin *ingenium,* which means a talent, natural capacity, or clever invention. Early applications of *clever inventions* often were military ones, and *ingeniarius* became one of several words applied to builders of such *ingenious* military machines.

Heritage of the Engineer. By whatever name, the roots of engineering lie much earlier than the time of the Romans, and the engineer today stands on the shoulders of giants. William Wickenden said this well in 1947:

> Engineering was an art for long centuries before it became a science. Its origins go back to utmost antiquity. The young engineer can say with truth and pride, "I am the heir of the ages. Tubal Cain, whom Genesis places seven generations after Adam and describes as the instructor of every artificer in brass and iron, is the legendary father of my technical skills. The primitive smelters of iron and copper; the ancient workers in bronze and forgers of steel; the discoverers of the lever, the wheel, and the screw; the daring builders who first used the column, the arch, the beam, the dome, and the truss; the military pioneers who contrived the battering ram and the catapult; the early Egyptians who channeled water to irrigate the land; the Romans who built great roads, bridges, and aqueducts; the craftsmen who reared the Gothic cathedrals; all these are my forbears. Nor are they all nameless. There are: Hero of Alexandria; Archimedes of Syracuse; Roger Bacon, the monk of Oxford; Leonardo da Vinci, a many-sided genius; Galileo, the father of mechanics; Volta, the physician; the versatile Franklin. Also, there are the self-taught geniuses of the industrial revolution: Newcomen, the ironmonger; Smeaton and Watt, the instrument makers; Telford, the stone mason; and Stephenson, the mine foreman; Faraday and Gramme; Perronet, Baker, and Roebling; Siemens and Bessemer; Lenoir and Lavassor; Otto and Diesel; Edison, Westinghouse, and Steinmetz; the Wright brothers, and Ford. These are representative of the trail blazers in whose footsteps I follow."

Beginnings of Engineering Education. Florman contrasts the French and British traditions of engineering education in his *Engineering and the Concept of the Elite,* and the following stems both from that and from Daniel Babcock's writings. In 1716 the French government, under Louis XV, formed a civilian engineering corps, the *Corps des Ponts et Chausées*, to oversee the design and construction of roads and bridges, and in 1747 founded the *Ecole des Ponts et Chausées* to train members of the corps. This was the first engineering school in which the study of mathematics and physics was applied not only to roads and bridges, but also to canals, water supply, mines, fortifications, and manufacturing. The French followed by opening other technical schools, most notably the renowned *Ecole Polytechnique* under the revolutionary government in 1794. In England, on the other hand, gentlemen studied the classics, and it was not until 1890 that Cambridge added a program in *mechanical science,* and 1909 when Oxford established a chair in *engineering science.* True, the Industrial Revolution began in England, but *[k]nowledge was gained pragmatically, in the workshop and on construction sites, and engineers learned their craft—and such science as seemed useful, by apprenticeship.*

America is heir to both traditions. Harvard and other early colleges followed the British classical tradition, and during the Revolutionary War, we borrowed engineers from France and elsewhere to help build (and destroy) military roads, bridges, and fortifications. "In the early days of the United

States, there were so few engineers—less than 30 in the entire nation when the Erie Canal was begun in 1817—that America had no choice but to adopt the British apprenticeship model. The canals and shops—and later the railroads and factories—were the 'schools' where surveyors and mechanics were developed into engineers. As late as the time of World War I, half of America's engineers were receiving their training 'on the job."'

The U.S. Military Academy was established in 1802, at the urging of Thomas Jefferson and others, as a school for engineer officers, but they did not distinguish themselves in the War of 1812. Sylvanus Thayer, who taught mathematics at the Academy, was sent to Europe to study at the *Ecole Polytechnique* and other European schools; on his return in 1817 as superintendent of the Academy, he introduced a four-year course in civil engineering, and hired the best instructors he could find. As other engineering schools opened, they followed this curriculum and employed Academy graduates to teach from textbooks authored by Academy faculty. Florman continues:

> Perhaps the most crucial event in the social history of American engineering was the passage by Congress of the Morrill Act—the so-called "land grants" act—in 1862. This law authorized federal aid to the states for establishing colleges of agriculture and the so-called "mechanic arts." The founding legislation mentioned "education of the industrial classes in their several pursuits and professions in life." With engineering linked to the "mechanic arts," and with engineers expected to come from the "industrial classes," the die was cast. American engineers would not be elite polytechnicians. They would not be gentlemen attending professional school after graduation from college [as law and medicine became]. . . . Engineering was to be studied in a four-year undergraduate curriculum.

Engineering as a Profession

The first issue (1866) of the English journal *Engineering* began with a description of

> the profession of the engineer as defined in the charter that Telford obtained [in 1818 for the Institute of Civil Engineers] for himself and his associates from [King] George the Fourth—"the art of directing the great sources of power in nature, for the use and convenience of man."

A more modern definition was created in 1979 by American engineering societies, acting together through the Engineers' Council for Professional Development (ECPD), the precursor to ABET (previously the Accrediting Board for Engineering and Technology). ECPD's definition focused on the application of math and science knowledge to develop novel solutions for the benefit of mankind.

This definition was modernized again in 2013 by the International Engineering Alliance (whose members include ABET). This update expands the definition to acknowledge the potential adverse consequences of engineering activity and note the ethical responsibility of engineers to to manage these risks and safeguard society and the environment.

Certainly, engineering meets all the criteria of a proud profession. Engineering undergraduates recognize the need for "intensive preparation" to master the specialized knowledge of their chosen profession, and practicing engineers understand the need for lifelong learning to keep up with the march of technology. In Part V of this book, we look at engineering societies and their ethical responsibilities in maintaining standards of conduct. Finally, engineers provide a public service not only in the goods and services they create for the betterment of society, but also by placing the safety of the public high on their list of design criteria. Each generation of engineers has the opportunity and obligation to preserve and enhance by its actions the reputation established for this profession by its earlier members.

What Engineers Do

Engineering. Before a description of engineers can be made, the term *engineering* must be defined. We can define engineering as follows:

> En-gi-neer-ing *n*: a branch of science and technology concerned with the invention, design, building, maintenance, and improvement of structures, machines, devices, systems, materials, and processes.

In other words, engineering is the means by which people make possible the realization of human dreams by extending our reach in the real world. Engineers are the practitioners of the art of managing the application of science and mathematics, a practice that is generally accomplished through projects. By this description, engineering has a limitless variety of possible disciplines.

Engineers. Engineering has been differentiated from other academic paths by the need for people to logically apply quantifiable principles. Academic knowledge, practical training, experience, and work-study are all avenues to becoming an engineer. The key attribute for engineers is the direct application of that knowledge and experience. The most up-to-date information on opportunities available for engineers can be found at various websites on the internet, industry publications, professional associations, and personal contacts within industry. Like other fields of endeavor, engineering no longer represents a static career choice. The basic idea is to be adept, adaptable, and aware.

Types of Engineers. The rigid classification of engineers into specific specialties and careers has been eroding swiftly. Many engineering applications require cross-pollination or integration of multiple disciplines. Aerospace engineers require knowledge of metallurgy, electronic control systems, computers, production limitations and possibilities, finance, life cycle logistic planning, and customer service. These are all required to produce a viable commercial product such as an airliner or a fighter. The previous focus on a speciality is no longer as important as being able to communicate and team with others. These teams are composed of various specialists knowledgeable in several primary fields. The primary specialization allows the engineer to contribute in a core area. This knowledge is required to properly integrate and implement the ideas of others. Along those lines, the list of core technologies is expanding and mutating rapidly. During the early age of computers, the late 1950s, software engineers were electrical engineers. The computer operating systems were custom tailored to the internal logic design. As advances in design created the need for software specialists, the electrical engineers evolved into software engineers. Today, software engineers are split among the various types of applications. Desktop, internet, server, Internet of Things (IoT), and mobile operating system gurus are eagerly sought in a wide variety of industries. A similar process can be observed in construction, mechanical systems, chemical engineering, and industrial engineering. Another indicator of the change in engineering has been the development of the field of engineering technology. Engineering technology emerged in direct response to industry needs for a person having a practical applications education. Experience and training will increasingly determine an engineer's actual specialty. Adding to the confusion is the expectation that a person will change careers five or more times in their life, a trend that accelerates with each new generation. Flexibility and interpersonal skills will be the hallmark of the new generation of engineering disciplines.

Engineering Employment. Traditional paths for a career in engineering have mirrored other fields of employment. Rarely will a person work for the same employer for their entire working lifetime. The simple fact is that the corporations and firms of the past no longer exist. Those currently in existence will have to change to meet the needs of customers. Employment opportunities lie with companies of all sizes. Greater size can mean greater work stability, albeit usually limited flexibility. This limitation is accompanied by the fact that larger firms have greater resources to implement change. A smaller firm may be less stable, but can rapidly adapt to changing circumstances. Unfortunately, smaller firms have fewer resources to respond to the changing circumstances. This means that engineers of the future should expect to be constantly improving their skills and marketability. Continuing education, flexibility, and a willingness to shift employment will be required of successful engineers.

Government employment traditionally meant steady employment with a relatively secure career path. This situation changed as government embraced business-based practices to reduce costs by outsourcing and contracting. A greater reliance on information technologies also reduced the workforce requirements through better communications. Although a large number of engineers remain employed by various governmental agencies, their main focus is evolving into oversight managers and controllers. Seniority currently guides progression in government service. However, the same forces found in the civilian market will generate a similar need in government employment for flexibility, continuing education, and willingness to switch jobs.

Engineering Jobs in an Organization. Organizations of all types, from manufacturing to retail and financial services to government offer many types of jobs for engineers. Figure 1-1 displays a depiction of a basic organization chart for Amazon.com, along with some of the types of engineering positions available within the company. Amazon is a large and complex business, with engineers in roles throughout, including many in technology, research and design (R&D), and operations. The role of engineering positions in research and design is discussed in Chapters 9 and 10. Engineering functions in operations are discussed in Chapters 11 and 12. The more technically complex the product, the more engineers will be involved in technical sales, field service engineering, and logistics support, as discussed in Chapter 13. Finally, we discuss how in today's age of technical complexity, many general management positions are held by engineers.

MANAGEMENT

Management Defined

The Australian Edmund Young, in supplementary notes used in teaching from the original edition of this chapter, wrote that

> "[m]anagement" has been one of the most ubiquitous and misused words in the 20th century English language. It has been a "fad" word as well. Civil engineers discuss river basin management and coastal management, doctors discuss disease management and AIDS management, and garbage collectors are now waste management experts.

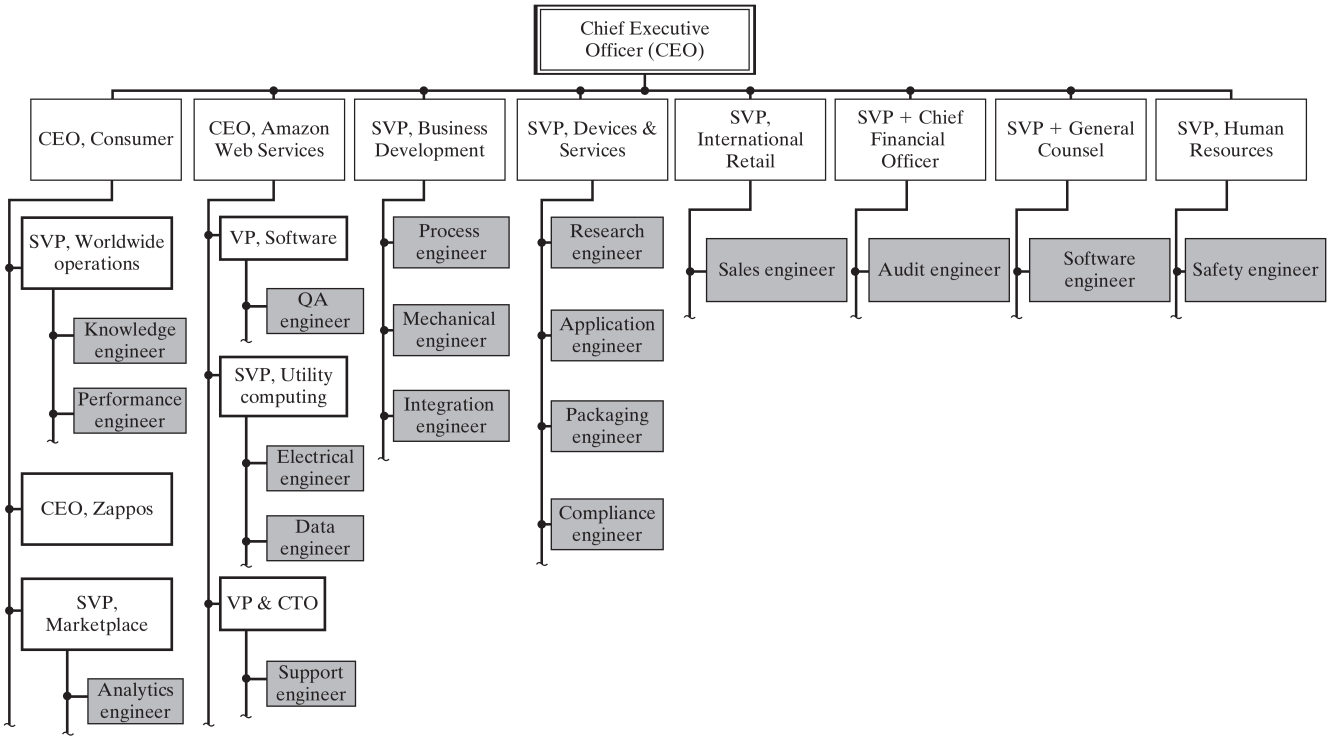

Figure 1-1 Selection of engineering roles in the organization of Amazon.com.

McFarland traces the meaning of the words *manage* and *management* as follows:

> The word *manage* seems to have come into English usage directly from the Italian *maneggiare*, meaning "to handle," especially to handle or train horses. It traces back to the Latin word *manus*, "hand." In the early sixteenth century *manage* was gradually extended to the operations of war and used in the general sense of taking control, taking charge, or directing.... *Management* was originally a noun used to indicate the process for managing, training, or directing. It was first applied to sports, then to housekeeping, and only later to government and business.

McFarland continues by identifying "four important uses of the word *management*, as (1) an organizational or administrative process; (2) a science, discipline, or art; (3) the group of people running an organization; and (4) an occupational career." Sentences illustrating each of these in turn might be (1) "He practices good management"; (2) "She is a management student"; (3) "Management *doesn't really believe* in quality"; and (4) (heard from innumerable college freshmen) "I want to get into management." Of these four, most authors of management textbooks are referring to the first meaning (the *process*) when they define "management." According to some of these authors, management is defined in the following ways:

- The work of creating and maintaining environments in which people can accomplish goals efficiently and effectively (Albanese)
- The process of achieving desired results through efficient utilization of human and material resources (Bedeian)
- The process of reaching organizational goals by working with and through people and other organizational resources (Certo)
- 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)
- The process by which managers create, direct, maintain, and operate purposive organizations through coordinated, cooperative human effort (McFarland)
- The process of acquiring and combining human, financial, informational, and physical resources to attain the organization's primary goal of producing a product or service desired by some segment of society (Pringle, Jennings, and Longnecker)

Albanese provides a set of definitions of the word *management* suggested by a sample of business executives:

- Being a respected and responsible representative of the company to your subordinates
- The ability to achieve willing and effective accomplishments from others toward a common business objective
- Organizing and coordinating a profitable effort through good decision making and people motivation
- Getting things done through people
- The means by which an organization grows or dies
- The overall planning, evaluating, and enforcement that goes into bringing about "the name of the game"—profit
- Keeping your customers happy by delivering a quality product at a reasonable cost
- Directing the actions of a group to accomplish a desired goal or objective in the most efficient manner

Management Levels

Ensign or admiral, college president or department chair, maintenance foreman, plant manager, or company president—all are managers. What skills must they have, what roles do they play, what functions do they carry out, and how are these affected by the level at which they operate? Let us look at each of these questions in order.

Management is normally classified into three levels: first-line, middle, and top. Managers at these three levels need many of the same skills, but they use them in different proportions. The higher the management level is, the further into the future a manager's decisions reach, and more resources placed at risk.

First-line managers directly supervise nonmanagers. They hold titles such as foreman, supervisor, or section chief. Generally, they are responsible for carrying out the plans and objectives of higher management, using the personnel and other resources assigned to them. They make short-range operating plans governing what will be done tomorrow or next week, assign tasks to their workers, supervise the work that is done, and evaluate the performance of individual workers. First-line managers may only recently have been appointed from among the ranks of people they are now supervising. They may feel caught in the middle between their former coworkers and upper management, each of which feels the supervisor should be representing them. Indeed, they must provide the *linking pin* between upper management and the working level, representing the needs and goals of each to the other.

Many engineers who go into a production or construction environment quickly find themselves assigned as a foreman or supervisor. The engineer may find such an assignment a satisfying chance to make things happen through their own actions and decisions. Doing so effectively, while according the workers the courtesy and respect merited by their years of experience, requires tact and judgment. If the engineer can achieve this balance, they may be surprised to find that the team members are respectful in return and are helpful to the engineer in learning *their* job.

Middle managers carry titles such as plant manager, division head, chief engineer, or operations manager. Although there are more first-line managers than any other in most organizations, most of the *levels* in any large organization are those of middle management. Even the lowest middle manager (the second-line manager, who directly supervises first-line managers) is an *indirect manager* and has the fundamentally different job of managing the efforts of employees through other managers. Middle managers make intermediate range plans to achieve the long-range goals set by top management, establish departmental policies, and evaluate the performance of the units and people in their organization. Middle managers also integrate and coordinate the short-range decisions and activities of first-line supervisory groups to achieve the long-range goals of the enterprise. Over the last two generations, middle management positions have decreased as organizations became "flatter" in an effort to become more competitive and get closer to their customers.

Top managers bear titles such as chairman of the board, president, or executive vice president; the top one of these will normally be designated *chief executive officer* (CEO). In government, the top manager may be the administrator (of NASA), secretary (of state or commerce), governor, or mayor. While top managers may report to some policymaking group (the board of directors, legislature, or council), they have no full-time manager above them.

Top managers are responsible for defining the character, mission, and objectives of the enterprise. They must establish criteria for and review long-range plans. They evaluate the performance of major departments, and evaluate leading management personnel to gauge their readiness for promotion to key executive positions. Bedeian paints a picture of the typical top manager: a college graduate (85 percent), probably with some postgraduate work (58 percent) and often a graduate degree (40 percent); usually from a middle-class background, often born to parents in business or a profession; age 50 to 65, with work experience concentrated in one, two, or three companies; and with a work week of 55 to 65 hours. Often, an organization will look for a top manager with particular strength in the functional area in which the enterprise is currently facing a challenge.

Managerial Skills

Katz suggests that managers need three types of skills: technical, interpersonal, and conceptual. *Technical skills* are skills (such as engineering, accounting, machining, or word processing) practiced by the group supervised. Figure 1-2 shows that the lowest level managers have the greatest need for technical skills, since they are directly supervising the people who are doing the technical work, but even top managers must understand the underlying technology on which their industry is based. *Interpersonal skills*, on the other hand, are important at every management level, since every manager achieves results through the efforts of other people. *Conceptual skills* represent the ability to "see the forest for the trees"—to discern the critical factors that will determine an organization's success or failure. This ability is essential to the top manager's responsibility for setting long-term objectives for the enterprise, although it is necessary at every level.

Managerial Roles—What Managers Do

Henry Mintzberg gives us another way to view the manager's job by examining the varied *roles* a manager plays in the enterprise. He divides them into three types: *interpersonal*, *informational*, and *decisional* roles, further described as follows:

- *Interpersonal* roles are primarily concerned with the manager's interactions with other people. This role can be as figurehead, focused on appearances and outward relationships; leader, focused on people below them in the organization; and liaison, focused on horizontal relationships and networking.

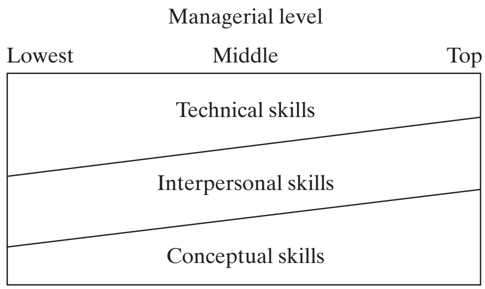

Figure 1-2 Blend of skills required at different management levels.

- *Informational* roles encompass how a manager exchanges and processes information. This role can be viewed as monitor, who collects information from inside and outside the organization; disseminator, who provides information to others within the organization; and spokesperson, who provides information to those outside the organization.
- *Decisional* roles describe how a manager uses information to make decisions. This role includes the entrepreneur, who initiates change and assumes risk; disturbance handler, who works to resolve problems or crises; resource allocator, who determines how the organization's resources of time and money are distributed; and negotiator, who handles bargaining and agreements inside and outside the organization.

Functions of Managers

Henri Fayol, the famous French mining engineer and executive, divided managerial activities into five elements: planning, organizing, command, coordination, and control. These elements, now called **functions of managers**, have proven remarkably useful and durable over the decades. Although each management author has their favored set of functions, almost all include planning, organizing, and controlling on their list. Command has become too authoritative a word in today's participative society and has been replaced by leading, motivating, or actuating. Few authors treat coordinating as a separate function. Nonetheless, as the late management author Harold Koontz concluded, "There have been no new ideas, research findings, or techniques that cannot readily be placed in these classifications." Koontz chose and (with coauthor Heinz Weihrich) defined his favored list of the functions of managers as follows:

- **Planning** involves selecting missions and objectives and the actions to achieve them; it requires decision making—choosing future courses of action from among alternatives.
- **Organizing** is that part of managing that involves establishing an intentional structure of roles for people to fill in an enterprise.
- **Staffing** [included with *organizing* by most authors] involves filling, and keeping filled, the positions in the organizational structure.
- **Leading** is influencing people to strive willingly and enthusiastically toward the achievement of organization and group goals. It has to do predominantly with the interpersonal aspect of managing.
- **Controlling** is the measuring and correcting of activities of subordinates to ensure that events conform to plans.

Engineering managers need to understand the body of knowledge that has been developed by management theorists and practitioners and organized under this framework, and this is the purpose of Part II of this book. Today the accepted functions of management are planning, organizing, leading, and controlling. Leading and motivating are treated in Chapter 3, planning and the associated subfunction of decision making are treated in Chapters 4 and 5, organizing in Chapters 6 and 7, and controlling in Chapter 8. Wherever possible, the particular implications of these functions for the technical employee and the technology-affected organization are emphasized.

The engineering manager also needs to understand the particular problems involved in managing research, development, design, production/operations, projects, and related technical environments. Parts III and IV treat the application of these management functions to the specific environments in which most engineers and engineering managers will work.

Management: Art or Science?

Earlier in this chapter the characteristics of a profession were discussed, and engineering was shown to meet all the criteria of a profession. Management also has a body of *specialized knowledge*, which is introduced in Part II. Many managers will have first completed bachelor's or master's degree programs in business administration, public administration, or engineering management, but the following applies, as Babcock has observed elsewhere:

> The knowledge need not be obtained only in such formal programs. It may be acquired by personal study, in-house employee education programs, seminars by all kinds of consultant entrepreneurs, or programs of many professional societies. Sometimes this formal or informal education is obtained before promotion [into] the management hierarchy, but often it occurs after promotion.
>
> A very small proportion of the broad range of managers belong to management-specific organizations such as the American Management Association, the Academy of Management, or (for engineers) the American Society for Engineering Management. They are more likely (especially in technical areas) to belong to management divisions or institutes within discipline-oriented professional societies. Considerations of standards, ethics, certification, and the like become those of the parent societies, not the management subset.

ENGINEERING MANAGEMENT: A SYNTHESIS

What Is Engineering Management?

Some writers would use a narrow definition of "engineering management," confining it to the direct supervision of engineers or of engineering functions. This would include, for example, supervision of engineering research or design activities. Others would add an activity we might consider the *engineering of management*—the application of quantitative methods and techniques to the practice of management (often called *management science*). However, these narrow definitions fail to include many of the management activities engineers actually perform in modern enterprises.

If engineering management is broadly defined to include the general management responsibilities engineers can grow into, one might well ask how it differs from *ordinary* management.

> The engineering manager is distinguished from other managers because they possesses both an ability to apply engineering principles and a skill in organizing and directing people and projects. They are uniquely qualified for two types of jobs: the management of *technical functions* (such as design or production) in almost any enterprise, or the management of broader functions (such as marketing or top management) in a *high-technology enterprise*.

Other Engineering Management Definitions

Engineering management is the art and science of planning, organizing, allocating resources, and directing and controlling activities that have a technological component.	American Society for Engineering Management
Engineering management is designing, operating, and continuously improving purposeful systems of people, machines, money, time, information, and energy by integrating engineering and management knowledge, techniques, and skills to achieve desired goals in technological enterprise through concern for the environment, quality, and ethics.	Omurtag (1988)
Engineering management is the discipline addressed to making and implementing decisions for strategic and operational leadership in current and emerging technologies and their impacts on interrelated systems.	IEEE (1990) and Kocaoglu (1991)

Source: Timothy Kotnour and John V. Farr, "Engineering Management: Past, Present, and Future," *Engineering Management Journal*, vol. 17, no. 1, March 2005.

Need for Engineers in Management

Herbert Hoover, a very successful mining engineer and manager, recognized the importance of the American engineering manager in an address to engineers the year he was elected president of the United States:

> Three great forces contributed to the development of the engineering profession. The first was the era of intense development of minerals, metallurgy, and transportation in our great West. . . . Moreover, the skill of our engineers of that period owes a great debt to American educators. The leaders of our universities were the first of all the educators of the world to recognize that upon them rested the responsibility to provide fundamental training in the application of science to engineering under the broadening influence and cultivation of university life. They were the first to realize that engineering must be transformed into a practice in the highest sense, not only in the training and character but that the essential quality of a profession is the installation of ethics. . . . A third distinction that grew in American engineering was the transformation from solely a technical profession to a profession of administrators—the business manager with technical training.

There are several reasons engineers can be especially effective in the general management, especially in technically oriented organizations. High-technology enterprises make a business of doing things that have never been done before. Therefore, extensive planning is needed to make sure that everything is done right the first time—there may not be a second chance. Planning must emphasize recognizing and resolving the uncertainties that determine whether the desired product or outcome is feasible. Since these critical factors are often technical, the engineer is best capable of recognizing them and managing their resolution. In staffing a technically based enterprise, engineering managers can best evaluate the capability of technical personnel when they apply for positions and rate their later performance. Further, they will better understand the nature and motivation of the technical specialist and can more easily gain their respect, confidence, and loyalty. George H. Heilmeier, president and CEO of Bellcore (and an electrical engineer), makes clear the advantages of an understanding of technology in top management:

Competition is global, and the ability to compete successfully on this scale is fostered by corporate leaders who can do the following:

- Understand the business at a deep level.
- Understand both the technology that is driving the business today and the technology that will change the business in the future.
- Treat research and development as an investment to be nurtured, rather than an expense to be minimized.
- Spend more time on strategic thinking about the future as they rise higher in the corporation.
- Be dedicated to solving a customer's problem or satisfying a need.
- Place a premium on innovation.

Management and the Engineering Career

It is common for engineers to move into a management role or pursue management-related advanced degrees. A 2006 study by the National Science Foundation found over 15 percent of those employed 10 years after earning an engineering degree hold a management role. That percentage grows to over 20 percent about 10 years later. The Bureau of Labor Statistics currently records the total employment for engineering managers to be over 180,000, with a 5.5 percent increase expected by 2026. Despite this, undergraduate engineering education offers little preparation for such a possibility. To meet this need, many engineering schools now provide degree programs and courses in engineering management. These courses and programs blend business and engineering, as shown in Figure 1-3. Professional societies are an additional way engineers may improve their managerial skills with many providing a variety of educational opportunities. Many engineering related professional socities (e.g. the American Society of Mechanical Engineers, the Institute of Industrial and Systems Engineers, etc.) have subgroups for engineering management. In addition, the American Society for Engineering Management (ASEM) is solely dedicated to development of Engineering Management professionals.

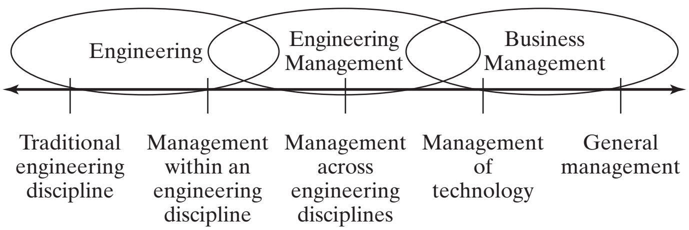

Figure 1-3 The field of engineering management.

Tim Cook: Picture of the Successful Engineering Manager

As CEO of Apple, Tim Cook is one of the most famous business leaders in the world and almost every profile of him makes prominent mention of his background in engineering. Cook graduated from Auburn University in 1982 with a Bachelor of Science in Industrial Engineering and later earned an MBA from Duke University. The skills developed in his industrial engineering education and how he used those skills at IBM and Compaq are prominent reasons that Steve Jobs recruited Cook to join Apple in 1998 where his first position was Senior Vice President of Worldwide Operations.[1] Tasked with improving Apple's complex supply chain, at that time a severe drag on the company's performance—Apple lost nearly 33 percent of its market value in the two years prior to him joining—Cook developed a system that continues to enable the company's product innovation. The results were almost immediate, and two years after Cook's arrival, Apple's value had increased over 460 percent and today it is commonly the most valuable company in the world and the first to reach $1 trillion in valuation. Cook recognizes the importance of blending both engineering and management skills and as an advisor at his alma mater has pushed for both excellence in technical education and well-rounded engineers.[2] He has noted that as "an engineer, you want to analyze things a lot. But if you believe that the most important data points are people, then you have to make conclusions in relatively short order."[3] As CEO, Cook has exemplified the tenants of the engineering profession to serve society and engineering ethics (see Chapter 16), dramatically increasing the company's charitable giving, social outreach, and recently stating "Whatever you do in your life, and whatever we do at Apple, we must infuse it with the humanity that each of us is born with."[4]

Source: Tobias Hase/dpa picture alliance/Alamy Stock Photo

Sources

1. Weinberger, M. *The rise of Apple CEO Tim Cook, the most powerful business leader in the world*. Business Insider, 2016.
2. Davis, K., *Tim Cook, Apple CEO and Auburn alum, discusses his time spent at Auburn*, in *The Auburn Plainsman*. 2014, Auburn University: Auburn, AL.
3. Lashinsky, A., *Apple's Tim Cook leads different*, in *Fortune*. 2015.
4. Cook, T. *Full transcript: Tim Cook delivers MIT'S 2017 commencement speech*. Quartz, 2017.

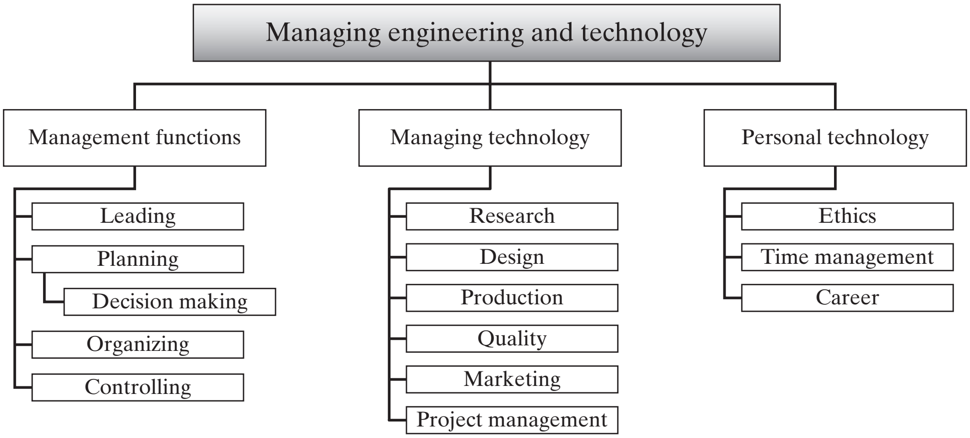

Figure 1-4 Managing engineering and technology text organization.

This book provides some insight into the nature of management and the environments in which the engineer is most likely to encounter the need for an understanding of management as their career progresses. Chapters 3 through 8 examine the functions of technology management. Chapters 9 through 13 examine the management of technology through the product life cycle. In the last three chapters, the career implications for the engineer moving to management are considered. The organization of these concepts within the book is shown in Figure 1-4.

DISCUSSION QUESTIONS

1-1. The precursors of today's engineers listed in the quotation from Wickenden had no classes and few or no books from which to learn scientific principles. How can you explain their success?

1-2. Create your argument for why *engineering management* is different than *management*. Why is this field needed?

1-3. Why is it so difficult to answer the simple question "How many engineers are there in the United States?" Is the question "How many physicians are there in the United States?" any easier? Why or why not?

1-4. Compare and contrast the role of the engineer with the role of the manager. How are they similar and how are they different?

1-5. What are the similarities in the definitions of *management* quoted from authors of management textbooks? How do you define *management*?

1-6. How does the job of supervisor or first-line manager differ from that of a middle manager?

1-7. Engineers often move into management of their organizations. Explain the ways that an engineering degree prepares an individual for this transition? What are the problems with this path?

1-8. Identify the three types of skills needed by an effective manager, as conceived by Robert L. Katz, and describe how the relative need for them might vary with the level of management.