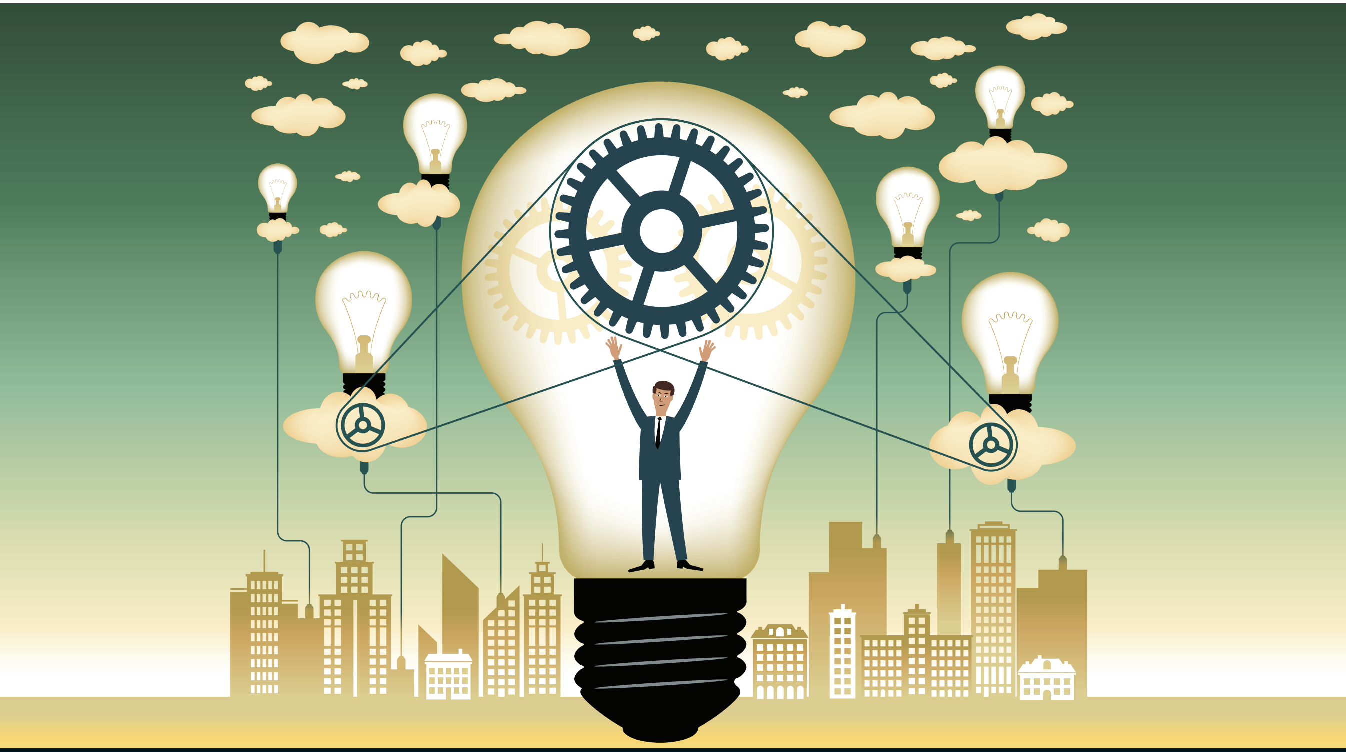
INTERNATIONAL EDITION

Managing Engineering and Technology

SIXTH EDITION

Lucy C. Morse • Daniel L. Babcock



ALWAYS LEARNING

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Pearson Education Limited
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Authorized adaptation from the United States edition, entitled Managing Engineering and Technology, Sixth Edition, ISBN 978-0-13-348510-3, *by Lucy C. Morse and Daniel L. Babcock, published by Pearson Education © 2014.*

ISBN 10: 0-273-79322-5
ISBN 13: 978-0-273-79322-9 (Print)
ISBN 13: 978-0-273-79395-3 (PDF)

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

10 9 8 7 6 5 4 3 2 1
14 13 12 11 10

Typeset in Times LT Std-Roman by Integra Software Services Pvt. Ltd.
Printed and bound by Courier Westford in The United States of America

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This edition is dedicated to Donald D. Myers (1939–2009),
a valued colleague and friend.

Contents

Preface

Welcome to the latest edition of *Managing Engineering and Technology.* This book is different from the previous one since today's technological society is constantly progressing, and with the progress comes a need for the engineer to be able to address the technological societal challenges and opportunities for the future. Engineers are a key element today in the role that any country must play to maintain technological leadership and a sound economy while 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 and be prepared for a creative and productive life and position of leadership.

This book is intended to be an overview of the field of engineering management; yet, realistically we recognize that the faculty adopting this text will want to tailor the content to their specific needs. The basic outline of the text remains unchanged. The text examines the four main management functions followed by the functions of technology management. As we worked with various reviewers and faculty on this edition it became apparent that today there are several primary concerns for the engineering manager. These include engineering ethics, leadership, and globalization. The sixth edition of the text addresses these concerns and has incorporated lessons learned from earlier editions, student and faculty comments, and our own personal teaching experience.

Some of the changes for this edition include the following:

- Emphasis on leadership. The four fundamental management functions are presented, but leadership is now first.
- Additional material on ethics.
- Globalization is considered more.
- New reference section at the end of each chapter, including Web sites for many chapters.
- An expanded Web site includes PowerPoint slides for each chapter, test banks, and solutions for instructors: www.pearsoninternationaleditions.com/Morse.
- Morse & Babcock's EM Blog: A Blog for Engineering Management Educators (http://morseandbabcock.wordpress.com/). This blog contains current material pertaining to engineering management and additional reference and project material.

The authors of this textbook will remain alert to changing customers, products, processes, technologies, and opportunities for engineering management and management of technology students. Again, suggestions for the improvement of the text are always welcome. We hope that the changes made in this edition of *Managing Engineering and Technology* will be helpful to instructors and students alike.

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Acknowledgments

Before I recognize several important contributors to this textbook I would like to say how honored I am to have had the opportunity to work with Dan Babcock. His initial vision for this book is much admired and I thank him for it. It is also important to thank and recognize the many teaching and working professionals who have provided insight and information for this edition and the five editions before. These include: Henry Metzner, Professor Emeritus, Missouri S&T; Jean Babcock; Ted Eschenbach, Professor Emeritus of Engineering Management at the University **of** Alaska Anchorage; John Scheiter, co-founder of Global Spec; Thomas A Crosby, President/CEO of Pal's Sudden Service; Charles W. Keller, University of Kansas, retired; Brian Goldiez, Deputy Director of the Institute of Simulation and Training, University of Central Florida; Klaus Garbers of European Foundation for Quality Management; Lee Lowery, Jr., Texas A&M University; Nabeel Yousef, Daytona State College; Ray Morrison, President, ACETS Consulting; C. Steven Griffin, General Manager CSR; and my colleagues in American Society for Engineering Management and American Society for Engineering Education. A special thanks to the recent reviewers: Stanley Bullington, Mississippi State University; Gus Elias, California State University-Northridge; Shih-Ming Lee, Florida International University; Thomas Siems, Southern Methodist University.

Finally, many thanks to my most understanding husband and good-natured critic, Jack Selter, and to Pearson for their support and patience, especially Program Manager Clare Romeo.

The publishers wish to thank Himadri Roy Chaudhuri of IMI, Kolkata for reviewing the content of the International Edition.

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Part I

Introduction to Engineering Management

1

Engineering and Management

PREVIEW

Today's technological society is constantly changing, and with the 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 that 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, and be prepared for a creative and productive life and position of leadership.

To assist the engineer 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 the typical 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 and complete definition was created in 1979 by American engineering societies, acting together through the Engineers' Council for Professional Development (ECPD), the precursor to the Accrediting Board for Engineering and Technology (ABET). ECPD defined *engineering* as

> the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgement to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind

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. *Webster's Ninth New Collegiate Dictionary*, 1989, defines engineering as follows:

> En-gi-neer-ing *n* 1: the art of managing engines 2: the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to man in structures, machines, products, systems, 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. 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 the industry. Like other fields of endeavor, engineering no longer represents a staid 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 focusing on a specialty is not 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. Internet, mainframe server, PC, and operating system gurus are eagerly sought. This same 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 a new field called 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 his or her life. 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 his or her 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 manpower 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. Manufacturing organizations offer many types of jobs for engineers, as shown in Figure 1-1. Many of the engineering positions in this hypothetical manufacturing company hierarchy fall under the heading of vice president of research and engineering. Positions in engineering research, engineering design, and related design support activities such as reliability and maintainability engineering are discussed in Chapters 9 and 10. Industrial, plant, maintenance, manufacturing, and quality engineering functions 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. A smaller number of engineers will find temporary positions or permanent careers in areas such as purchasing

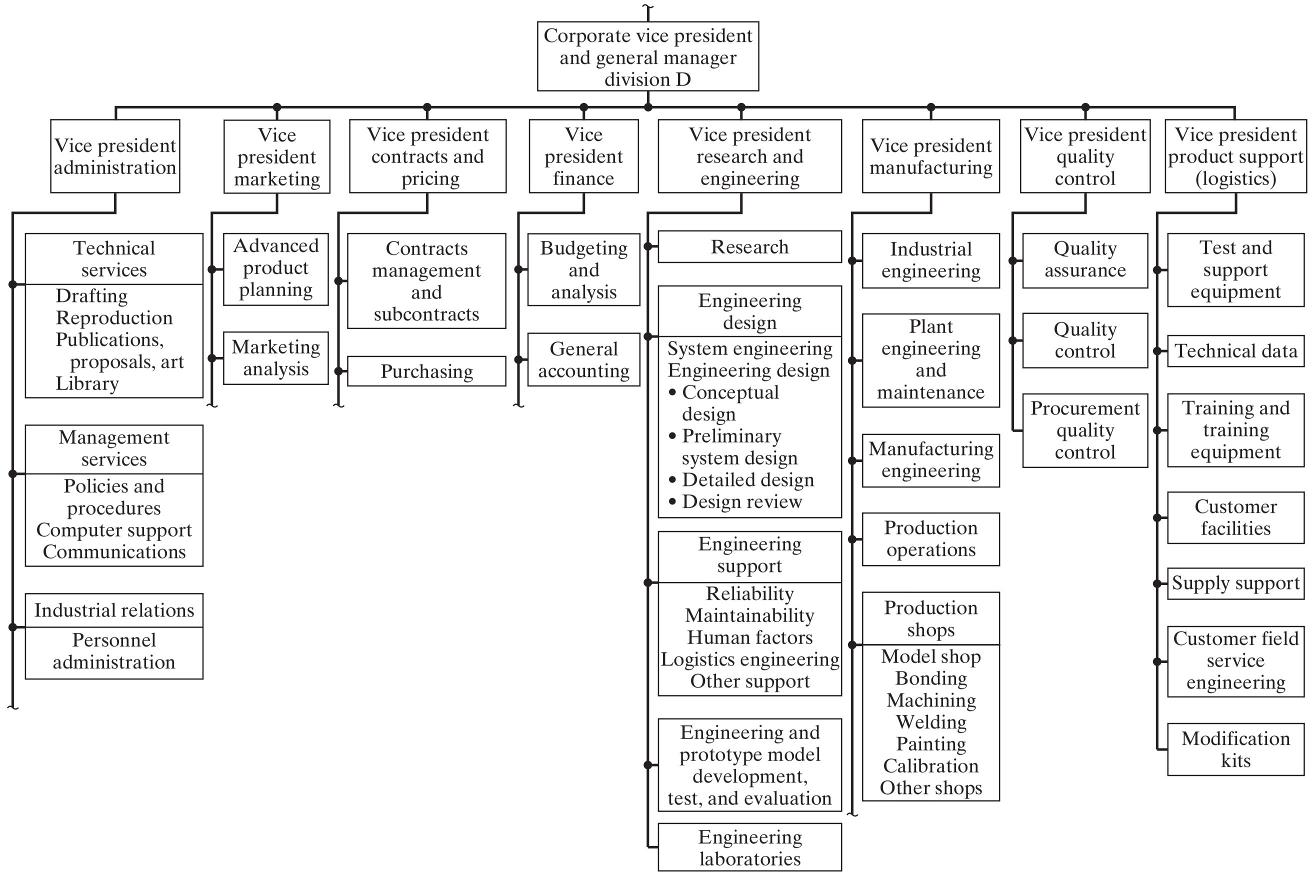

Figure 1-1 Engineering activities within a division of a large corporation. (From Benjamin S. Blanchard, *Engineering Organization and Management*, © 1976, Figure 10-3, p. 280. Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, NJ).