


Thirteenth Edition




Niebel's Methods, Standards, and Work Design

Andris Freivalds

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About the Authors

Andris Freivalds is professor of industrial engineering at the Pennsylvania State University. He obtained a B.S. degree in science engineering and M.S. and Ph.D. degrees in bioengineering from the University of Michigan. After biomechanics research at the Aerospace Medical Research Laboratory at Wright Patterson AFB, Ohio, and at the University of Nottingham, U.K., as a Fulbright Scholar, he shifted his focus to the reduction of work-related musculoskeletal injuries in U.S. industries. With the assistance of the Commonwealth of Pennsylvania in the development of the Center for Cumulative Trauma Disorders (CTD), he has provided ergonomic and engineering design services to more than 75 Pennsylvania companies in controlling their workplace hazards and improving overall productivity. As part of these efforts, he was recognized by the Institute of Industrial Engineers with its Technical Innovation Award in 1995. He is a Certified Professional Ergonomist and a Fellow of the Ergonomics Society.

Benjamin Niebel received B.S., M.E., and P.E. degrees in industrial engineering from the Pennsylvania State University. After heading the industrial engineering department at Lord Manufacturing Company, he became interested in engineering education. He returned to Penn State as a faculty member in 1947 and then served as the head of the Department of Industrial Engineering from 1955 to 1979. During this time he wrote many textbooks, including the original *Motion and Time Study* in 1955, and consulted regularly with many industries. For his outstanding service to both the profession and Penn State, he was awarded the Frank and Lillian Gilbreth Award by the Institute of Industrial Engineers in 1976, the Outstanding Engineering Alumnus Award by the College of Engineering in 1989, and the Penn State Engineering Society Distinguished Service Award in 1992. He passed away at the distinguished age of 80 while on a consulting trip for industry.

To Benjamin W. Niebel (1918–1999), who reminded me to remember productivity while designing work for health and safety.

Brief Contents

Table of Contents

Preface

BACKGROUND

Faced with increasing competition from all parts of the world, almost every industry, business, and service organization is restructuring itself to operate more effectively. As downsizing and outsourcing become more common, these organizations must increase the intensity of cost reduction and quality improvement efforts while working with reduced labor forces. Cost-effectiveness and product reliability without excess capacity are the keys to successful activity in all areas of business, industry, and government and are the end result of methods engineering, equitable time standards, and efficient work design.

Also, as machines and equipment grow increasingly complex and semiautomated (if not fully automated), it is increasingly important to study both the manual components and the cognitive aspects of work as well as the safety of the operations. The operator must perceive and interpret large amounts of information, make critical decisions, and control these machines both quickly and accurately. In recent years, jobs have shifted gradually from manufacturing to the service sector. In both sectors, there is increasingly less emphasis on gross physical activity and a greater emphasis on information processing and decision making, especially via computers and associated modern technology. The same efficiency and work design tools are the keys to productivity improvement in any industry, business, or service organization, whether in a bank, a hospital, a department store, a railroad, or the postal system. Furthermore, success in a given product line or service leads to new products and innovations. It is this accumulation of successes that drives hiring and the growth of an economy.

The reader should be careful not to be swayed or intimidated by the latest jargon offered as a cure-all for an enterprise's lack of competitiveness. Often these fads sideline the sound engineering and management procedures that, when properly utilized, represent the key to continued success. Today we hear a good deal about reengineering and use of cross-functional teams as business leaders reduce cost, inventory, cycle time, and nonvalue activities. However, experience in the past few years has proved that cutting people from the payroll just for the sake of automating their jobs is not always the wise procedure. The authors, with many years of experience in more than 100 industries, strongly recommend sound methods engineering, realistic standards, and good work design as the keys to success in both manufacturing and service industries.

WHY THIS BOOK WAS WRITTEN

The objectives of the thirteenth edition have remained the same as for the twelfth: to provide a practical, up-to-date college textbook describing engineering methods to measure, analyze, and design manual work. The importance of ergonomics and work design as part of methods engineering is emphasized, not only to increase productivity, but also to improve worker health and safety and thus company bottom-line costs. Far too often, industrial engineers have focused solely on increasing productivity through methods changes and job simplification, resulting in overly repetitive jobs for the operators and increased incidence rates of musculoskeletal injuries. Any cost reductions obtained are more than offset by the increased medical and workers' compensation costs, especially considering today's ever-escalating health-care costs.

WHAT'S NEW IN THE THIRTEENTH EDITION

A new Section 16.4 on standards in service work has been added, showing application of work measurement to call centers and health care. Approximately 10 to 15 percent more examples, problems, and case studies have been added. The thirteenth edition still provides a continued reliance on work design, work measurement, facilities layout, and various flow process charts for students entering the industrial engineering profession, and serves as a practical, up-to-date source of reference material for the practicing engineer and manager.

HOW THIS BOOK DIFFERS FROM OTHERS

Most textbooks on the market deal strictly either with the traditional elements of motion and time study or with human factors and ergonomics. Few textbooks integrate both topics into one book or, for that matter, one course. In this day and age, the industrial engineer needs to consider both productivity issues and their effects on the health and safety of the worker simultaneously. Few of the books on the market are formatted for use in the classroom setting. This text includes additional questions, problems, and sample laboratory exercises to assist the educator. Finally, no text provides the extensive amount of online student and instructor resources, electronic forms, software tools, current information, and changes as this edition does.

ORGANIZATION OF THE TEXT AND COURSE MATERIAL

The thirteenth edition is laid out to provide roughly one chapter of material per week of a semester-long introductory course. Although there are a total of

18 chapters, Chapter 1 is short and introductory, much of Chapter 7 on cognitive work design and Chapter 8 on safety may be covered in other courses, and Chapter 15 on standards for indirect and expense work may not have to be covered in an introductory course, all of which leaves only 15 chapters to be covered in the semester.

A typical semester plan, chapter by chapter, using the first lecture number, might be as follows:

Chapter	Lectures	Coverage
1	1	Quick introduction on the importance of productivity and work design, with a bit of historical perspective.
2	3–6	A few tools from each area (Pareto analysis, job analysis/worksite guide, flow process charts, worker– machine charts) with some quantitative analysis on worker–machine interactions. Line balancing and PERT may be covered in other courses.
3	4	Operation analysis with an example for each step.
4	4	Full, but can gloss over basic muscle physiology and energy expenditure.
5	4	Full.
6	3–4	Basics on illumination, noise, temperature; other topics as desired may be covered in another course.
7	0–4	Coverage depends on instructor’s interest; may be covered in another course.
8	0–5	Coverage depends on instructor’s interest; may be covered in another course.
9	3–5	Three tools: value engineering, cost-benefit analysis, and crossover charts; job analysis and evaluation, and interaction with workers. Other tools may be covered in other classes.
10	3	Basics of time study.
11	3–5	One form of rating; first half of the allowances that are well established.
12	1–3	Coverage of standard data and formulas depends on instructor’s interest.
13	4–7	Only one predetermined time system in depth; the second may be covered in another course.
14	2–3	Work sampling.
15	0–3	Coverage of indirect and expense labor standards depends on instructor’s interest.
16	2–3	Overview and costing.
17	3–4	Day work and standard hour plan.
18	3–4	Learning curves, motivation, and people skills.

The recommended plan covers 43 lectures, with 2 periods for examinations. Some instructors may wish to spend more time on any given chapter, for which additional material is supplied, for example, work design (Chapters 4 to 7), and less time on traditional work measurement (Chapters 8 to 16), or vice versa. The text allows for this flexibility.

Similarly, if all the material is used (the second lecture number), there is enough material for one lecture course and one course with a lab, as is done at Penn State University. Both courses have been developed with appropriate materials such that they can be presented completely online. For an example of an online course using this text, go to *www.engr.psu.edu/cde/courses/ie327/index.html*

SUPPLEMENTARY MATERIAL AND ONLINE SUPPORT

The thirteenth edition of this text continues to focus on the ubiquitous use of PCs as well as the Internet to establish standards, conceptualize possibilities, evaluate costs, and disseminate information. A website, hosted by the publisher at *http://highered.mcgraw-hill/sites/0073376310/*, furthers that objective by providing the educator with various online resources, such as an updated instructor's manual. DesignTools version 4.1.1, a ready-to-use software program for ergonomics analysis and work measurement, appears on the site as well. A special new feature of DesignTools is the addition of QuikTS, a time study data collection app for the iPad and iPhone.

The book's website also links to a website hosted by the author at *www2.ie.psu.edu/Freivalds/courses/ie327new/index.html,* which provides instructors with online background material, including electronic versions of the forms used in the textbook. Student resources include practice exams and solutions. Up-to-date information on any errors found or corrections needed in this new edition appear on this site as well. Suggestions received from individuals at universities, colleges, technical institutes, industries, and labor organizations that regularly use this text have helped materially in the preparation of this thirteenth edition. Further suggestions are welcome, especially if any errors are noticed. Please simply respond to the OOPS! button on the website or by email to *axf@psu.edu*

ACKNOWLEDGMENTS

I wish to acknowledge the late Ben Niebel for providing me with the opportunity to contribute to his well-respected textbook. I hope the additions and modifications will match his standards and continue to serve future industrial engineers as they enter their careers. Thanks to Mr. Jaehyun Cho for devoting so much of his time at Penn State to programming QuikTS. Thanks also to the following reviewers for their invaluable input:

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Andris Freivalds

CHAPTER 1

Methods, Standards, and Work Design: Introduction

KEY POINTS

- Increasing productivity drives U.S. industry.
- Worker health and safety are just as important as productivity.
- Methods engineering simplifies work.
- Work design fits work to the operator.
- Time study measures work and sets standards.

1.1 PRODUCTIVITY IMPORTANCE

Certain changes continually taking place in the industrial and business environment must be considered both economically and practically. These include the globalization of both the market and the producer, the growth of the service sector, the computerization of all facets of an enterprise, and the ever-expanding applications of the Internet and Web. The only way a business or enterprise can grow and increase its profitability is by increasing its productivity. Productivity improvement refers to the increase in output per work-hour or time expended. The United States has long enjoyed the world's highest productivity. Over the last 100 years, productivity in the United States has increased approximately 4 percent per year. However, in the past two decades, the U.S. rate of productivity improvement has been greatly exceeded by that of China, at 13.4 percent.

The fundamental tools that result in increased productivity include methods, time study standards (frequently referred to as work measurement), and work design. Of the total cost of the typical metal products manufacturing enterprise, 12 percent is direct labor, 45 percent is direct material, and 43 percent is overhead. All aspects of a business or industry—sales, finance, production, engineering, cost, maintenance, and management—provide fertile areas for the application of methods, standards, and work design. Too often, people consider only production, when other aspects of the enterprise could also profit from the application of productivity tools. In sales, for example, modern information retrieval methods usually result in more reliable information and greater sales at less cost.

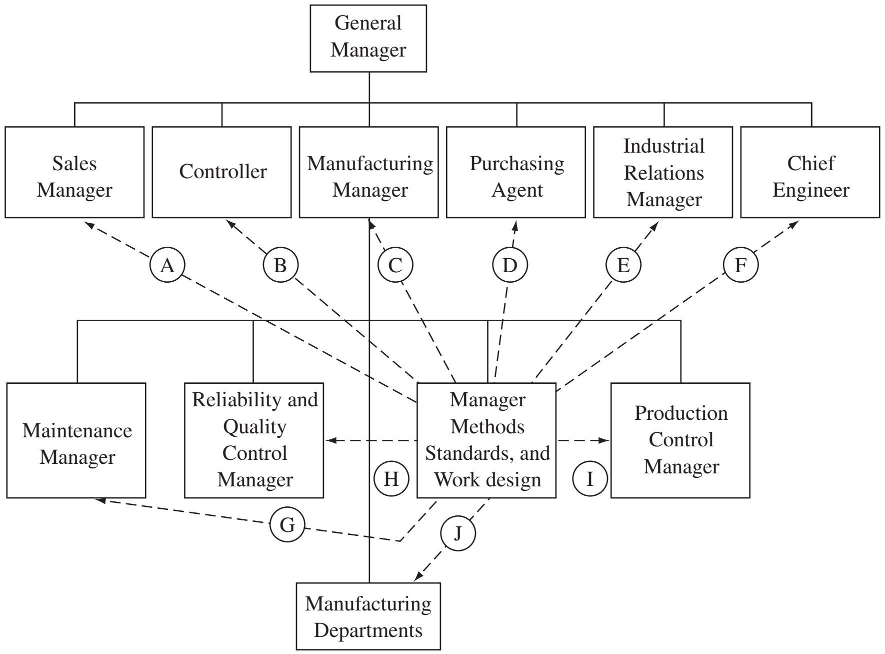
Today, most U.S. businesses and industries are, by necessity, restructuring themselves by downsizing, to operate more effectively in an increasingly competitive world experiencing a prolonged recession. With greater intensity than ever before, they are addressing cost reduction and quality improvement through productivity improvement. They are also critically examining all nonvalue business components, those that do not contribute to their profitability.

Traditional areas of opportunity for students enrolled in engineering, industrial management, business administration, industrial psychology, and labor–management relations are (1) work measurement, (2) work methods and design, (3) production engineering, (4) manufacturing analysis and control, (5) facilities planning, (6) wage administration, (7) ergonomics and safety, (8) production and inventory control, and (9) quality control. However, these areas of opportunity are not confined to manufacturing industries. They exist, and are equally important, in such enterprises as department stores, hotels, educational institutions, hospitals, banks, airlines, insurance offices, military service centers, government agencies, retirement complexes, and other service sectors. Today, in the United States, only about 10 percent of the total labor force is employed in manufacturing industries. The remaining 90 percent is engaged in service industries or staff-related positions. As the United States becomes ever more service-industry-oriented, the philosophies and techniques of methods, standards, and work design must also be utilized in the service sector. Wherever people, materials, and facilities interact to obtain some objective, productivity can be improved through the intelligent application of methods, standards, and work design.

The production area of an industry is key to success. Here materials are requisitioned and controlled; the sequence of operations, inspections, and methods is determined; tools are ordered; time values are assigned; work is scheduled, dispatched, and followed up; and customers are kept satisfied with quality products delivered on time.

Similarly, the methods, standards, and work design activity is the key part of the production group. Here more than in any other place, people determine whether a product is going to be produced on a competitive basis, through efficient workstations, tooling, and worker and machine relationships. Here is where they are creative in improving existing methods and products and maintaining good labor relations through fair labor standards.

The objective of the manufacturing manager is to produce a quality product, on schedule, at the lowest possible cost, with a minimum of capital investment and a maximum of employee satisfaction. The focus of the reliability and quality control manager is to maintain engineering specifications and satisfy customers with the product's quality level and reliability over its expected life. The production control manager is principally interested in establishing and maintaining production schedules with due regard for both customer needs and the favorable economics obtainable with careful scheduling. The maintenance manager is primarily concerned with minimizing facility downtime due to unscheduled breakdowns and repairs. Figure 1.1 illustrates the relationship of all these areas and the influence of methods, standards, and work design on overall production.



A—Cost is largely determined by manufacturing methods.
B—Time standards are the bases of standard costs.
C—Standards (direct and indirect) provide the bases for measuring the performance of production departments.
D—Time is a common denominator for comparing competitive equipment and supplies.
E—Good labor relations are maintained with equitable standards and a safe work environment.
F—Methods work design and processes strongly influence product designs.
G—Standards provide the bases for preventive maintenance.
H—Standards enforce quality.
I—Scheduling is based on time standards.
J—Methods, standards, and work design provide how the work is to be done and how long it will take.

Figure 1.1
Typical organization chart showing the influence of methods, standards, and work design on the operation of the enterprise.

1.2 METHODS AND STANDARDS SCOPE

Methods engineering includes designing, creating, and selecting the best manufacturing methods, processes, tools, equipment, and skills to manufacture a product based on the specifications that have been developed by the product engineering section. When the best method interfaces with the best skills available, an efficient worker–machine relationship exists. Once the complete method has been established, a standard time for the product must be determined. Furthermore, there is the responsibility to see that (1) predetermined standards are met; (2) workers are adequately compensated for their output, skills, responsibilities, and experience; and (3) workers have a feeling of satisfaction from the work that they do.

The overall procedure includes defining the problem; breaking the job down into operations; analyzing each operation to determine the most economical manufacturing procedures for the quantity involved, with due regard for operator safety and job interest; applying proper time values; and then following through to ensure that the prescribed method is put into operation. Figure 1.2 illustrates

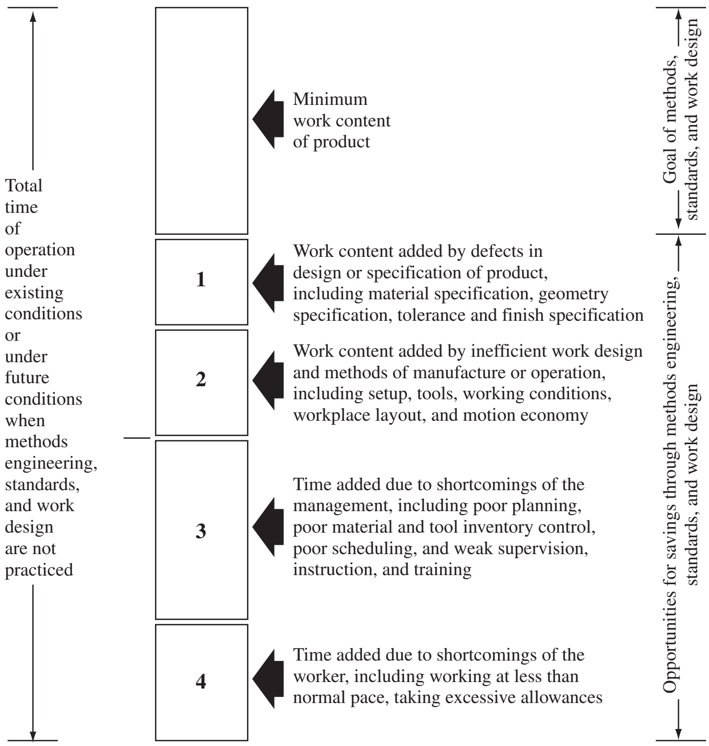


Figure 1.2
Opportunities for savings through the applications of methods engineering and time study.

the opportunities for reducing the standard manufacturing time through the application of methods engineering and time study.

METHODS ENGINEERING

The terms *operation analysis, work design, work simplification, methods engineering,* and *corporate reengineering* are frequently used synonymously. In most cases, the person is referring to a technique for increasing the production per unit of time or decreasing the cost per unit output—in other words, productivity improvement. However, methods engineering, as defined in this text, entails analyses at two different times during the history of a product. First, the methods engineer is responsible for designing and developing the various work centers where the product will be produced. Second, that engineer must continually restudy the work centers to find a better way to produce the product and/or improve its quality.

In recent years, this second analysis has been called corporate reengineering. In this regard, we recognize that a business must introduce changes if it is to continue profitable operation. Thus, it may be desirable to introduce changes outside the manufacturing area. Often, profit margins may be enhanced through positive changes in such areas as accounting, inventory management, materials requirements planning, logistics, and human resource management. Information automation can provide dramatic rewards in all these areas. The more thorough the methods study during the planning stages, the less the necessity for additional methods studies during the life of the product.

Methods engineering implies the utilization of technological capability. Primarily because of methods engineering, improvements in productivity are never-ending. The productivity differential resulting from technological innovation can be of such magnitude that developed countries will always be able to maintain competitiveness with low-wage developing countries. Research and development (R&D) leading to new technology is therefore essential to methods engineering. The 10 countries with the highest R&D expenditures per worker, as reported by the 2012 Global Innovation Index are Israel, Finland, Sweden, Japan, South Korea, Denmark, Switzerland, Germany, United States, and Austria. These countries are among the leaders in productivity. As long as they continue to emphasize research and development, methods engineering through technological innovation will be instrumental in their ability to provide high-level goods and services.

Methods engineers use a systematic procedure to develop a work center, produce a product, or provide a service (see Figure 1.3). This procedure is outlined here, and it summarizes the flow of the text. Each step is detailed in a later chapter. Note that steps 6 and 7 are not strictly part of a methods study, but are necessary in a fully functioning work center.

1. *Select the project.* Typically, the projects selected represent either new products or existing products that have a high cost of manufacture and a low profit. Also, products that are currently experiencing difficulties in

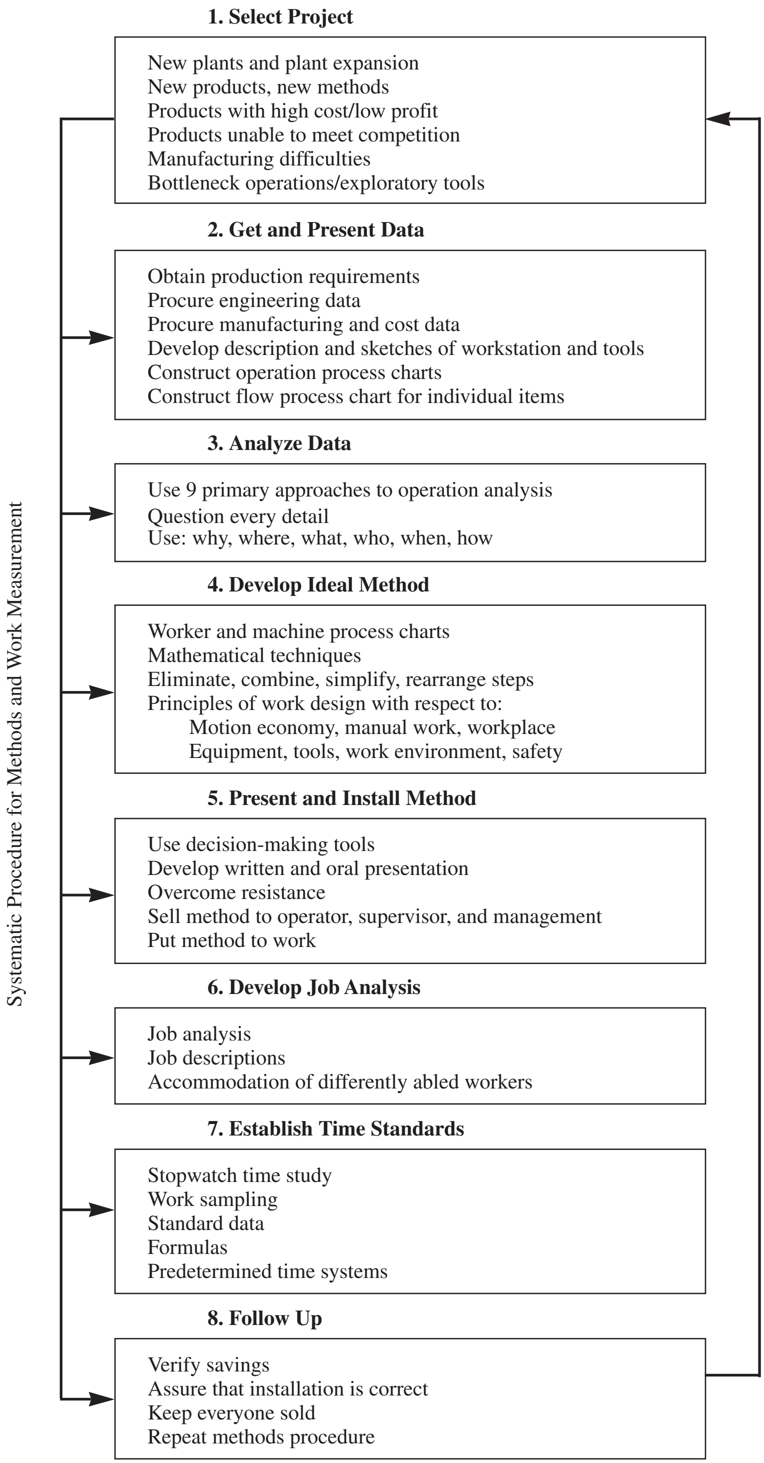


Figure 1.3
The principal steps in a methods engineering program.

maintaining quality and are having problems meeting competition are logical projects for methods engineering. (See Chapter 2 for more details.)

2. *Get and present the data.* Assemble all the important facts relating to the product or service. These include drawings and specifications, quantity requirements, delivery requirements, and projections of the anticipated life of the product or service. Once all important information has been acquired, record it in an orderly form for study and analysis. The development of process charts at this point is very helpful. (See Chapter 2 for more details.)
3. *Analyze the data.* Utilize the primary approaches to operations analysis to decide which alternative will result in the best product or service. These primary approaches include purpose of operation, design of part, tolerances and specifications, materials, process of manufacture, setup and tools, working conditions, material handling, plant layout, and work design. (See Chapter 3 for more details.)
4. *Develop the ideal method.* Select the best procedure for each operation, inspection, and transportation by considering the various constraints associated with each alternative, including productivity, ergonomics, and health and safety implications. (See Chapters 3 to 8 for more details.)
5. *Present and install the method.* Explain the proposed method in detail to those responsible for its operation and maintenance. Consider all details of the work center, to ensure that the proposed method will provide the results anticipated. (See Chapter 9 for more details.)
6. *Develop a job evaluation.* Conduct a job analysis of the installed method to ensure that the operators are adequately selected, trained, and rewarded. (See Chapter 9 for more details.)
7. *Establish time standards.* Establish a fair and equitable standard for the installed method. (See Chapters 10 to 15 for more details.)
8. *Follow up the method.* At regular intervals, audit the installed method to determine if the anticipated productivity and quality are being realized, whether costs were correctly projected, and whether further improvements can be made. (See Chapter 16 for more details.)

In summary, methods engineering is the systematic close scrutiny of all direct and indirect operations to find improvements that make work easier to perform, in terms of worker health and safety, and also allow work to be done in less time with less investment per unit (i.e., greater profitability).

WORK DESIGN

As part of developing or maintaining the new method, the principles of work design must be used to fit the task and workstation ergonomically to the human operator. Unfortunately, work design is typically forgotten in the quest for increased productivity. Far too often, overly simplified procedures result in machinelike repetitive jobs for the operators, leading to increased rates of work-related musculoskeletal disorders. Any productivity increases and reduced costs are more than offset by the increased medical and workers' compensation costs, especially considering today's ever-escalating health-care trends. Thus, it is necessary for the methods engineer to incorporate the principles of work design into any new method, so that it not only will be more productive but also will be safe and injury-free for the operator. (Refer to Chapters 4 to 8.)

STANDARDS

Standards are the end result of time study or work measurement. This technique establishes a time standard allowed to perform a given task, based on measurements of the work content of the prescribed method, with due consideration for fatigue and for personal and unavoidable delays. Time study analysts use several techniques to establish a standard: a stopwatch time study, computerized data collection, standard data, predetermined time systems, work sampling, and estimates based on historical data. Each technique is applicable to certain conditions. Time study analysts must know when to use a given technique and must then use that technique judiciously and correctly.

The resulting standards are used to implement a wage payment scheme. In many companies, particularly in smaller enterprises, the wage payment activity is performed by the same group responsible for the methods and standards work. Also, the wage payment activity is performed in concert with those responsible for conducting job analyses and job evaluations, so that these closely related activities function smoothly.

Production control, plant layout, purchasing, cost accounting and control, and process and product design are additional areas closely related to both the methods and standards functions. To operate effectively, all these areas depend on time and cost data, facts, and operational procedures from the methods and standards department. These relationships are briefly discussed in Chapter 16.

OBJECTIVES OF METHODS, STANDARDS, AND WORK DESIGN

The principal objectives of methods, standards, and work design are (1) to increase productivity and product reliability safely and (2) to lower unit cost, thus allowing more quality goods and services to be produced for more people. The ability to produce more for less will result in more jobs for more people for a greater number of hours per year. Only through the intelligent application of the principles of methods, standards, and work design can producers of goods and services increase, while, at the same time, the purchasing potential of all consumers grows. Through these principles, unemployment and relief rolls can be minimized, thus reducing the spiraling cost of economic support to nonproducers.

Corollaries to the principal objectives are as follows:

1. Minimize the time required to perform tasks.
2. Continually improve the quality and reliability of products and services.

3. Conserve resources and minimize cost by specifying the most appropriate direct and indirect materials for the production of goods and services.
4. Consider the cost and availability of power.
5. Maximize the safety, health, and well-being of all employees.
6. Produce with an increasing concern for protecting the environment.
7. Follow a humane program of management that results in job interest and satisfaction for each employee.

1.3 HISTORICAL DEVELOPMENTS

THE WORK OF TAYLOR

Frederick W. Taylor is generally conceded to be the founder of modern time study in this country. However, time studies were conducted in Europe many years before Taylor's time. In 1760, Jean Rodolphe Perronet, a French engineer, made extensive time studies on the manufacture of No. 6 common pins, while 60 years later, an English economist, Charles W. Babbage, conducted time studies on the manufacture of No. 11 common pins.

Taylor began his time study work in 1881 while associated with the Midvale Steel Company in Philadelphia. Although born into a wealthy family, he disdained his upbringing and started out serving as an apprentice. After 12 years' work, he evolved a system based on the "task." Taylor proposed that the work of each employee be planned out by the management at least one day in advance. Workers were to receive complete written instructions describing their tasks in detail and noting the means to accomplish them. Each job was to have a standard time, determined by time studies made by experts. In the timing process, Taylor advocated breaking up the work assignment into small divisions of effort known as "elements." Experts were to time these individually and use their collective values to determine the allowed time for the task.

Taylor's early presentations of his findings were received without enthusiasm, because many of the engineers interpreted his findings to be a new piece-rate system rather than a technique for analyzing work and improving methods. Both management and employees were skeptical of piece rates, because many standards were either typically based on the supervisor's guess or inflated by bosses to protect the performance of their departments.

In June 1903, at the Saratoga meeting of the American Society of Mechanical Engineers (ASME), Taylor presented his famous paper "Shop Management," which included the elements of scientific management: time study, standardization of all tools and tasks, use of a planning department, use of slide rules and similar timesaving implements, instruction cards for workers, bonuses for successful performance, differential rates, mnemonic systems for classifying products, routing systems, and modern cost systems. Taylor's techniques were well received by many factory managers, and by 1917, of 113 plants that had installed "scientific management," 59 considered their installations completely successful, 20 partly successful, and 34 failures (Thompson, 1917).