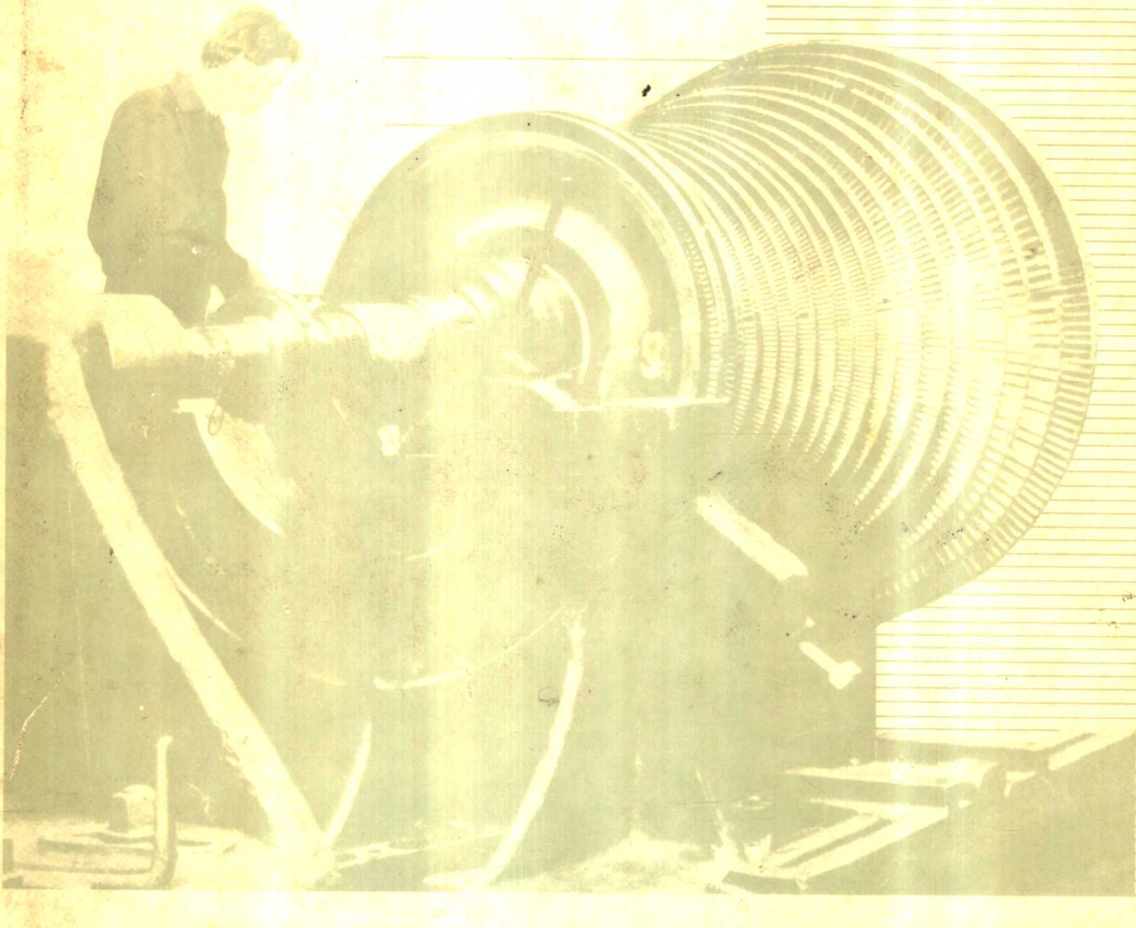
METHODS ANALYSIS AND WORK MEASUREMENT

Edward J. Polk



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PREFACE

Much of the material in this book is taken from a manual published by and for General Motors Institute. This manual has served General Motors Corporation and GMI Engineering and Management Institute admirably and in a variety of ways since it was written 20 years ago. It is based on the combined experience, knowledge, and expertise of many practicing supervisors of industrial engineering who, through participation on committees and task groups, devised many of the specific models presented and laid the basic philosophical foundations for their application to the never-ending search for "the one best way." Fortunately, the coauthors and I have been contributing members of these various committees and task groups through the years.

In the intervening time, the manual has been revised and expanded, thus benefiting from the viewpoints and varied perspectives of more recent additions to the faculty of the Industrial and Systems Engineering Department at GMI. This book, constituting a major revision, should continue to function well as a basic text for methods analysis and work measurement courses at the sophomore or junior class level. This purpose has been well served at GMI for both industrial engineering and industrial administration students for whom the course is a requirement. Portions of the text are also used for a two-week continuing engineering education program which has been operating in its present form for over 15 years, and is intended to provide newcomers to this aspect of industrial engineering with some fundamental "tools of the trade," or to provide some polish for those whose skills may have become a bit rusty. In addition, selected sections have been used in seminars and training programs conducted in various plant locations throughout the United States and in Canada, England, France, West Germany, and Brazil. The usual emphasis in these latter uses is on cost reduction and productivity improvement, involving a wide cross section of personnel from production and staff support groups. Many millions of dollars in savings have been documented as a result of these efforts.

This book has been organized to present the material in a sequence corresponding to the typical order in which the various topics are presented in teaching the course. Alternate sequences are certainly feasible and are left to the discretion of the instructor. An instructor's guide offers several alternatives, as well as specific chapters recommended for short courses, seminars, and similar purposes.

The overall thrust of this book is to first establish a solid philosophical base, recognizing the historical precedents for the profession of industrial engineering and reestablishing a too-often forgotten notion that the ultimate long-term success of any enterprise, however measured, depends on the properly directed and adequately rewarded efforts of people. With this foundation we move on to cover a big-picture view of systems analysis, followed by the tools of methods analysis and design, and proceed to work-measurement techniques and other related topics. It is no accident that the latter two topics appear in that sequence. We have long recognized the concept of inseparability of method and time; thus, if time, the dependent variable, is to be conserved and used wisely, one must first deal with the method and all factors affecting performance. This is not an industrial engineering handbook; its scope is limited to only basic tasks of methods analysis and work measurement which are essential elements of the industrial engineering function. It is our desire that this book may offer in some respect a different or new insight into the ways, whys, and worth of competent and professional approaches to these responsibilities, upon which so much of the business depends.

Finally, we would be remiss in not expressing our appreciation to several individuals whose efforts and influence over the years are still evident in some fashion in this text. To Ed Allen, Art Wright, Ned Gene Jones, George Reynolds, Walter Friess, Larry Cooper, and Robert Dettinger, former colleagues on the faculty of GMI, our thanks and appreciation are extended. Also, a debt of gratitude is owed by all who may derive benefit from this book to John Duncan and Ted Gobeske, formerly of GM Manufacturing Development Engineering, who were instrumental in organizing and guiding the early committee work upon which much of the original manual used at GMI was based. Sincere gratitude also goes to all the committee members who made contributions to this book.

Edward J. Polk

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CHAPTER
ONE
INTRODUCTION

From beginnings rooted primarily in the areas of methods analysis and work measurement, the industrial engineering profession has moved outward from this narrow-base concentration to encompass a widely expanded sphere of concern and influence. This trend is clearly evident on the one hand by the growth in numbers of practitioners found throughout the world of business, industry, government, and academia. It is further indicated by the variety of specialties represented in the field and included within the curriculums of most degree programs. Such areas of concentration as computer systems design, ergonomics, quality control and reliability, manufacturing and assembly systems design, production and material control, project management, and the economic evaluation of engineering alternatives are but a few which might be cited.

This expanding breadth of interest has been accompanied and facilitated by a similar expansion in the body of pertinent knowledge as well as by a phenomenal growth in technology applicable to the measurement and quantification of the characteristics of all types of systems. In particular, modern computer systems have revolutionized data-processing capabilities, permitting the application of mathematical tools of analysis and computation to real-world problems on scales of magnitude and complexity that had previously been unapproachable; in fact, this progress may be only a hint of what may occur in the next few years.

There is, however, a common factor or thread running through all the problems which face the managers of most organizations producing goods or services, whether private or public. This ubiquitous component is the cost of labor, which must still be measured, controlled, and utilized efficiently. Placing an accurate value on the time taken to perform work is still an essential part of the industrial engineer's responsibility. The successful management of any enterprise involves cost control, planning and estimating, development of budgets, and other activities, all of which involve great dependence on the reliability of these values. Decisions about making or buying a component, installing labor-saving machinery, or withdrawing from a particular line of business demand a solid information base, including the real cost of labor. The consequences of such decisions are often far reaching, not only touching upon the people directly involved but often rippling throughout an entire community.

It is particularly appropriate, therefore, to present a reprise of the basic elements of these traditional tasks with special emphasis on an organized approach to problem solving, critical analysis, and careful measurement. Underlying all these tools and techniques is a constant awareness of each worker's needs, capabilities, limitations, dignity, and value as a human being. No amount of effort by any staff or service group can guarantee the success of the enterprise unless the worker and the workplace are given top priority in the scheme of things. That in large measure is where the long-term success of any organization, as measured by profitability, begins and ends.

HISTORICAL PERSPECTIVES OF INDUSTRIAL ENGINEERING

As in most endeavors, a look backward at the beginnings often provides light for the future and appreciation for the efforts of the pioneers who opened some doors to the present and may most importantly provide the insight necessary for avoiding pitfalls and errors which were discovered early and forgotten of late.

One of the earliest references to sound management principles is found in the Bible, Exodus, chapter 18. An overwhelmed Moses is counseled by Jethro to relieve himself of petty details and minor matters by delegating to carefully selected subordinates the authority to render decisions on routine matters. Implementation of this principle of management by exception, hinges on the establishment of operating rules and policies within which the subordinates are empowered to act. Managers are thus able to apply their special skills and talents most effectively to the disposition of non-routine matters (the "exceptions") which do not meet the criteria for action by the subordinates.

Testimony to an even earlier achievement in technical skill and organization of resources is offered by the pyramids of Egypt. These massive structures, built by people and animals with only the most rudimentary machinery, raise a number of technical questions, many of which have not yet been answered. Given the size and precision of these massive structures, one is led to speculate that the architects supervising the design and construction must have used scale models (simulations) to avoid errors and devise methods of construction. The magnitude of this achievement is in no way diminished by the fact that unlimited human effort was used in lieu of machinery. Not only do the architectural and technical riddles remain, but the puzzle is compounded by new problems. The questions raised and still unanswered revolve around managing the concerted efforts of tens of thousands of people, providing direction and control, and solving the logistical problems of providing food and water for such numbers. Considerable executive and administrative talents in supply and distribution were clearly required.

The pictorial writings of that era also suggest an awareness of a need for organizational structure and identification of levels in the organization. Various kinds and classes of workers are distinguishable by their dress. An awareness of some principles of motion economy is also evidenced by the illustrations of the gang bosses responsible for enforcing order and, no doubt, generating dedication to the task at hand. They are repeatedly shown with one large club held high in the right hand and a long dagger held in the left hand. A second long dagger is positioned and located on the body so that it can be grasped with the least amount of motion in the event that it instead of the club was desired in the hand.

That the Roman Empire came to dominance and prevailed for so many years is attributable in part to great administrative skills in government and successful management of the military organization. Perhaps the Romans recognized the truth of an observation about the management of people reported in the Discourses of Socrates: "Those who know how to employ men, conduct either private or public affairs judiciously, while those who do not know will err in the management of both." One is thus led to speculate that when "employment" of men ceases to be a prime concern in any society, the resulting "mismanagement" leads to the eventual downfall of that society. There may be a lesson here for all of us.

It is clear in any case that the attempts to define management and to develop a science of management certainly predates Frederick Taylor and others who followed the scientific management principles which he espoused.

In 1776, Adam Smith wrote *An Inquiry Into the Nature and Cause of the Wealth of Nations,* not only a masterpiece on the economics of enterprise but also a clear statement of the basis for industrial efficiency. In 1832, Charles Babbage in his *Economy of Machinery and Manufacture* presented a masterful description and analysis of conditions in industry of the time and furnished a model method of studying those conditions. These efforts clarify the nature and bases for intelligent operation of business and industry and have been paralleled by many learned people in other parts of the western world at a time when industrialization was just beginning to emerge as a driving force which would have tremendous impact on society throughout the world.

SCIENTIFIC MANAGEMENT

The term "scientific management" was devised to describe principles of management developed and espoused by Frederick Taylor which were intended to bring to the industrial scene new problem-solving methods based on investigation and measurement. The purpose of these new ideas was to promote increased productivity and derive maximum benefit from all resources for the greatest good for the greatest number, with justice, increased opportunity, comfort, and happiness for all.

In preparation for hearings before the Interstate Commerce Commission and Congress relating to a request by the railroad operators for freight-rate increases, a group opposing the increases, including Louis Brandeis, later Justice Brandeis, expressed a need for a short name by which the subject of "science applied to management" could be identified more conveniently. Brandeis and his group were preparing to argue for better management and improved operations rather than increased freight rates. The

Taylor system among others was to be presented as an alternative approach to the fiscal problems of the railroads. The term scientific management was finally selected as being free from personalities and embodying the essential ideas of this new style of management of decision by measurement.

As often happens, however, the best intentions of well-meaning individuals may become entangled in politics, sensational journalism, and misinterpretation by the technical writers of the day. Many argued that there was a lack of scientific basis for Taylor's theories. In truth, if one requires a methodology by which hypotheses are developed and systematically tested against factual evidence acquired in a totally unbiased manner, much of Taylor's work would fall short. The term thus acquired a negative connotation and much adverse publicity. Taylor himself objected to it and would have preferred a term such as "measured functional management," also suggested at the time. This would perhaps have better served the cause of science in management, as well as being closer to what Taylor and his associates were advocating—a thoughtful and systematic approach to solving the problems of management.

The "science of management" implies much more than what the term scientific management came to mean to most early industrialists. It has evolved into a broad-based field of knowledge and applied technology firmly anchored in quantitative measurement and analysis. The discipline of industrial engineering continues to grow as a profession, with continuing emphasis on research to develop new tools and new applications of old ones, always dedicated to the proposition that effective utilization of all factors involved in an organization providing goods or services is essential to the survival of that organization, the well-being of everyone associated with it, and in the broader view, the ultimate well-being of the nation and society.

HISTORICAL FIGURES IN INDUSTRIAL ENGINEERING

Though any list of people who have in any way contributed must inevitably be incomplete, mention of a few seems entirely appropriate to further demonstrate the roots of the body of knowledge and the scope of applications as the profession has evolved over the years.

Adam Smith

Adam Smith, a British economist and author of *Wealth of Nations* (published in 1776), recognized and stated the principle of division of labor, which Babbage later restated, emphasizing its importance. Smith also recorded the divisions of work for manufacturing pins, listing 11 operations and the standard time and cost for each operation.

In his book, Smith discusses three basic economic advantages resulting from the division of labor: development of a skill or a dexterity when a single task is performed repetitively; a saving of time normally lost in changing over from one activity to the next; and invention of machines or tools that seem normally to follow when people specialize their efforts on tasks of restricted scope. The book was a milestone in the development of production economics, both because Smith's observations probably accelerated the division of labor and because this great scholar recognized that there existed a rationale for volume production.

Frederick Winslow Taylor (1856-1915)

Taylor came from a well-to-do Philadelphia family. He attended schools in France and Germany and New England's Phillips Exeter Academy, where he graduated at the top of his class. He had planned to study law at Harvard, passing entrance examinations with honors but at the cost of seriously impaired eyesight. Forced to give up the idea of further study at the age of 18, he obtained a job in a machine shop at the Cramp Shipyard in Philadelphia, where he served the apprenticeships of patternmaker and machinist.

In 1878, when Taylor's apprenticeship ended, he became a laborer at Midvale Steel Company, remaining there for the next 12 years. The friendship between Taylor's family and the W. W. Clark family, which owned a majority of the Midvale stock, probably helped his early advancements in the company. Though he started as a laborer, he became gang boss after 2 years and chief engineer after 4 years, when he was 28 years of age. During his early years at Midvale, Taylor studied at night and received a degree in mechanical engineering from Stevens Institute in 1883.

As a supervisor, Taylor first became aware of such problems as what was the best way to do a job and what constituted a day's work. Taylor thus realized that it was the employees rather than the employers who were running the various shops.

Taylor observed that "the workmen together had carefully planned just how fast each job should be done; they set a pace for each machine throughout the shop—limited to about one-third of a good day's work."

Taylor tried every expedient to get his workers to turn out more work. He fired stubborn employees and even hired untrained men and tried training them himself. Even though he urged his workers to produce more, he fully sympathized with their reluctance. Since the company reduced the piece rate as output increased, earnings were fixed regardless of what they produced.

That management hadn't the slightest idea what constituted a proper day's work shocked Taylor. So he set out to discover for himself just what the ingredients were. Taylor believed it was management's obligation to understand the workers and their jobs. He wanted individual jobs surveyed and a program worked out to ensure an orderly system guaranteeing maximum production at minimum cost.

After 12 years at Midvale, Taylor left to test his management theories with other firms. The most important of these was Bethlehem Steel Company. Here Taylor attempted to systematize management-employee communications, gather information on the qualities of cutting tools, and assess "correct" work methods.

One of Taylor's most noted experiments centered around the simple job of carrying pig iron (castings from a blast furnace) from yard pile to freight car. No one could conceive a more elementary example of mere physical effort. After watching his men load pig iron into freight cars from the storage yard, Taylor decided that they were not doing it the best way. He thought that they used the wrong motions and that they worked too hard and too long, becoming overtired and having to rest too long. He believed that the work would be less tiring if the workers did it differently and took frequent short rest periods.

The men were paid $1.15 a day, loading an average of 12 $\frac{1}{2}$ tons of pig iron per man per day. One person in the group named Schmidt was offered the opportunity to earn more money if he would follow directions on how to pick up, carry, and put down the pigs of iron, and to take frequent short rests. Taylor believed that in this way Schmidt could load more pig iron.

The results obtained were startling, as the figures in the table indicate. Schmidt

	Before tests	After completion of tests
Output per day per worker	12 $\frac{1}{2}$ tons	47 $\frac{1}{2}$ tons
Wages per day per worker	$1.15 per day	$1.85 per day
Labor cost per ton	9.2 cents	3.9 cents

followed the directions, loading 47 tons in one day and earning $1.85, and continued to do so thereafter. Some of the workers could not handle that much pig iron, but the company soon had many applicants for the $1.85 job.

With respect to the fatigue element, Taylor found that a worker handling 92-pound pigs should be under load less than 45 percent of the working period for best efficiency. Of course, this percentage would vary with the physical demand and would be higher with lighter loads.

A similar experiment was conducted on shoveling work. Taylor was not the first to study shoveling, but his study made the headlines. Taylor had a flair for the dramatic and received widespread attention for some of the things he did. He found that each person in the gang furnished his own shovel, and that the shovels were of various sizes. Sometimes the yard laborers had to shovel coal, sometimes iron ore, sometimes ashes. Hence the weight per shovelful varied considerably, depending on the material lifted. By experiment, he found that most work was done when a load of about 21 pounds was moved per shovelful. He had the company buy a stock of shovels of various sizes. No matter what the material shoveled, the appropriate size shovel could be furnished to the workers. Large shovels were used for ashes, and small shovels for iron ore. In such a way, the load was always about 21 pounds. As a result, the work done per worker increased and costs were reduced.

Significant conclusions were drawn from these and similar experiments. They demonstrated the importance of regulated rest periods (related to the human energy expended); standard methods of working; standard tasks (output quotas); adequate wage incentives; and proper selection and training of workers for each type of job.

With respect to the wage incentive, Taylor believed that the worker's best effort could be obtained only with wages based on output, and that the wage rate should enable superior workers to exceed their former earnings by 30 to 100 percent. Inadequate incentives would discourage extra cooperation and effort. Many employers who adopted the Taylor method of setting time standards and piece rates but failed to provide sufficient reward could not achieve desired objectives. Dissatisfied workers refused to cooperate.

Taylor's standard tasks were not easy ones; he placed dependence on *superior labor.* He believed that superior workers could be found for each class of work and that adequate wage incentives would reward such individuals for this superiority. He also believed that no one should be kept on a chance-assigned job for which he or she was ill-suited. He assumed that all workers could be placed at jobs within their individual capacities.

Experiments such as those conducted by Taylor pioneered the modern science of operation analysis, which includes motion study and time study. The experiments involved more than the simple process of cut, try, and record results. Methods and conclusions were *scientific* because of exhaustive investigations, extensive accumulation of factual data, analytical studies, and derivation of principles.

Taylor arrived at four fundamental principles which remain important today. Referring to managers and their duties, he summarized as follows:

> First, they develop a science for each element of a man's work which replaces the old rule of thumb method.
>
> Second, they scientifically select and then train, teach, and develop the workman, whereas in the past he chose his own work and trained himself as best he could.
>
> Third, they heartily cooperate with the men so as to insure all of the work being done in accordance with the principles of the science which has been developed.
>
> Fourth, there is an almost equal division of the work and responsibility between the management and the workmen. The management takes over all work for which they are better fitted than the workmen, while in the past almost all of the work and the greater part of the responsibility were thrown upon the men.[1]

Taylor developed a number of systems which he put into practice as manufacturing executive and consultant. These included forms of organization and a wage system. He emphatically pointed out, however, that basic principles were the essence of scientific management and that systems and detail procedures must be fitted to individual conditions and must be revised to accommodate new developments. This important concept was neglected by some efficiency experts who tried to obtain quick results by employing some elements of Taylor's methods while disregarding others. The results in such cases were not satisfactory. Taylor's differential piece rate and functional foremanship are now obsolete.

Taylor is sometimes referred to as the father of scientific management, but to credit him with originating it is claiming too much. He certainly did a great deal to develop the field of management as a science, but his greatest contribution was that of developing and dramatically publicizing the field of management. He was the movement's catalytic agent. His imagination and zeal in carrying through his investigations were perhaps equal to the task of originating the ideas. The fact is, however, that he arrived too late on the scene to be credited with the whole job. He himself said: "Hardly a single piece of original work was done by me in Scientific Management.

[1] F. W. Taylor, *The Principles of Scientific Management*, Harper & Bros., New York, 1929.

Everything that we have has come from a suggestion by someone else." However, Taylor is undoubtedly the outstanding historical figure in the development of the production management field. Others were observers and writers, but Taylor was both a thinker and a doer.

By the turn of the century, interest in improved shop-management technique had become more general. During this time, Taylor, who by then had become a consulting engineer, was prominent in management activities. In 1906, he was president of the American Society of Mechanical Engineers. He wrote numerous articles, most noteworthy of which were "A Piece Rate System" (1895) and "On the Art of Cutting Metal" (1906). His two books, *Shop Management* (1903) and *The Principles of Scientific Management* (1911), are classics in the literature of management.

Henry Laurence Gantt (1861-1919)

Gantt was born May 20, 1861, in Calvert County, Maryland. He graduated from Johns Hopkins University with a bachelor of arts degree at 19. He then taught for 3 years at the McDonough School in Baltimore County. In 1884, he received a degree in mechanical engineering from Stevens Institute of Technology.

Gantt began his industrial work at Midvale and Bethlehem Steel Companies in association with Frederick W. Taylor. This early union lasted for only a short time, because Gantt felt that Taylor's approach was too restrictive, owing to its mechanistic ideology. Gantt believed that there was far more to the industrial complex and went on to develop a concept that visualized industrial problems as national problems, with the human element being of prime importance. He placed strong emphasis upon properly trained management. Trained workers, according to Gantt, would not be sufficient if management lacked proper direction. He believed that business must produce service first, with rewards (profits) the by-product, because "reward according to service rendered is the only foundation on which our industrial and business system can permanently stand."

These principles were radical departures from the philosophy of his day, and it becomes apparent to the student of Gantt's teachings that modern devices do not always correct the situations which he encountered, but merely hide them from the untrained eye.

Gantt is remembered for initiating the concept of a task and bonus system, based on the notion that a reward for a good job would mean more in the long run than a penalty for a poor job. During his work with the Ordnance Department at the time of the first World War, the Gantt chart technique was developed.

In a talk before the ASME on November 30, 1961, Professor David B. Porter of New York University, a former associate of Gantt, described the Gantt chart's principles as follows:

> Mr. Gantt recognized that these charts were more than tools to aid in production planning and control. They are, in reality, effective measures of performance of those at all levels from workman to manager. The record is clear and the responsibilities for either good or poor performances are accurately placed. This is truly a democratizing performance force which causes

> control to gravitate from weak to strong hands, or as he (Gantt) put it, "to those who know what to do and how to do it." This reflects the philosophy of Gantt, who was impatient with any system which covered up the shortcomings of management and caused frustration and ill will within the organization.

Gantt was much interested in the new type of management as applied to all aspects of a business. He placed heavy responsibility on management and emphasized the principles of training, helping, and leading people rather than merely directing and driving.

Gantt was a close associate of Taylor, but later branched out as a consultant on his own. Gantt's and Taylor's viewpoints on management were in many respects the same, but Taylor emphasized analysis and organization of the work in solving problems and Gantt gave major attention to the people who were doing it. He insisted that willingness to use correct methods and skills in performing a task are as important as knowing the methods and having the skills in the first place. He thus perceived the weight of the human element in productivity and approached the concept of motivation as we understand it today.

Gantt described a task and bonus system of wage payments, which exemplified this point of view and had a far-reaching effect on compensation methods. As time passed, Gantt became increasingly interested in management's broad obligations to society. In *The Parting of the Ways,* published in 1919, he called for the return to a philosophy from which he felt management had departed—a return which gained momentum in the 1930s and has been strongly influential ever since.

Frank B. Gilbreth (1868-1924)

Gilbreth is the most prominent figure in the history of operation analysis, or motion study. Ably assisted by his wife Lillian, Gilbreth developed methods and principles which are the foundations of modern practice in this field. As Lillian expressed it; Frank was absorbed in "the quest for the one best way"—a search which was to lead far beyond the experiments of Taylor and other contemporaries.

Gilbreth's first classic experiment was in bricklaying, a skilled trade. As originally performed, this was a job exceedingly wasteful of skill and effort. Gilbreth was able to increase output per man-hour from 120 bricks to 360. He accomplished this by elimination of unnecessary movements, by full utilization of both hands, by simple new apparatus, and by the introduction of low-cost helpers. A special scaffold was devised, easily adjustable in height so that the bricklayer could work continuously at a convenient level. The unskilled assistant working below the scaffold sorted the bricks with best faces out and stacked them on standard pallets, which were then elevated to the masons. For various reasons, Gilbreth's and similar efforts to increase productivity did not appeal to labor organizations in the construction field. It seems probable that if labor had adopted his methods, construction costs could have been greatly reduced.

The bricklaying achievement was the first of a long series of experiments. Gilbreth later adopted a research tool not available to Taylor—the motion picture. Motion studies were formerly dependent on the stopwatch and the capacity of an observer to perceive, time, and record the various steps in a work operation. The movie camera detects details of motion too fast for the human eye to catch and produces a permanent record which can be studied in slow motion or frame by frame. As a result of extensive motion studies of many types of work, the Gilbreths developed two new and exceedingly important devices for operation analysis: (1) basic elements common to all human work operations and (2) principles of efficient motion. The basic elements of motions as defined by the Gilbreths were named "therbligs" (Gilbreth spelled backward, with the *th* transposed). Originally, there were 17 therbligs. Examples are search, select, grasp, transport (the hand) empty, transport (the hand) loaded, assemble, plan, and inspect. Although industrial engineers have changed or combined several of the original therbligs, the analysis of therbligs and their combinations is the basis for detailed motion studies of the present day.

The Gilbreth laws of efficient motion embody scientific principles which serve as guides to the analyst in determining the one best way for handling any manual job. As originally developed, there were 16 of these laws. To cite one example: "Motions of arms should be in opposite and symmetrical directions, instead of in the same directions, and made simultaneously." (This principle is based on the fact that by its observance, the body of the operator is kept in balance by the opposing arm movements, which eliminates the fatigue of turning or resisting motion at the shoulders, back, and hips.) Gilbreths' laws of efficient motion have also been revised and supplemented since their days.

The Gilbreths paralleled Gantt in their interest in human beings and human effort, applying to this interest an enormous capacity for organized detail. They explored many other important new areas of management. A common characteristic of their thinking was emphasis on the employee, as an individual, whose productivity depended on attitude, opportunity, and physical environment as much as the use of correct methods and ideal equipment. The Gilbreths' three-position plan of promotion proposed in 1916 anticipated by almost 40 years what is now called systematic management development.

The Gilbreth family of 12 children often participated in the work being done by this remarkable husband-wife team. They often served as subjects for studies ranging from bathing and brushing teeth to the touch system of typing.

Their books *Motion Study, Applied Motion Study,* and *The Psychology of Management* still make interesting and useful reading for the industrial engineer. In a lighter vein, *Cheaper by the Dozen* and *Bells on Their Toes* are amusing accounts of life in the Gilbreth family circle written by two of the younger Gilbreths.

Walter A. Shewhart

Shewhart, a young physicist of the Bell Telephone Laboratories, is credited with the development of the statistical control chart in 1924. Wrestling with a problem made complicated by the presence of random variation, he came to realize that the problem was statistical in nature. Some of the observed variation in performance was natural to the process and unavoidable. But from time to time there would be variations which could not be so explained.

He reached the brilliant conclusion that it would be desirable and possible to set limits upon the natural variation of any process, so that fluctuations within these limits could be readily explained by chance causes; but any variation outside this band would indicate a change in the underlying process. There followed the development of charts for measurement and control on attributes and variables, the concept of the rational subgroup and its use in most effectively letting the process set the limits of natural variability, and a large amount of practical experimentation in trying out the new methods on actual plant problems. In 1931, Shewhart produced his great text, *Economic Control of Quality of Manufactured Product,* in which the whole topic was laid out, including the theory, philosophy, applications, and most importantly, economic aspects. The field of industrial quality control gets its name from this book and control charts are often called Shewhart control charts.

L. H. C. Tippett

Tippett described a statistical method which he had developed in the English textile industry to measure operator and machine delays in 1934. He called his method the snap-reading method, finding it particularly effective for determining the causes of loom stoppages in the textile factories he was studying. Tippett states that around 1927 he was making time studies in the weaving sheds to discover how much of the productive capacity was lost for various causes.

As Tippett was observing his weaving sheds, he was on the lookout for methods of observation to collect data. One day a weaving manager remarked: "I can tell at a glance whether the weaving in the shed is good. If most of the weavers are bent over their looms mending a warp break, weaving is bad; if the weavers are mostly watching running looms, weaving is good." It became clear that a snapshot of the state of the looms in a shed taken at any instant was in some way an indication of the rate of production in a short interval surrounding that instant, and of the losses in output due to various causes.

Tippett saw at once that a snapshot of the looms taken at any instant would enable him to determine the production of the looms at that instant. Further study led him to develop the snap-reading method of analysis which later became known as ratio-delay studies. The current name for this technique is work sampling. Tippett, an outstanding mathematician and statistician, has a lŏng list of articles and publications to his credit in mathematical and statistical journals and texts.

Although presented from a variety of perspectives, each of these people was concerned with some measure of the efforts of people to achieve the goals of an organization. As suggested by these brief accounts, the basic principles of work design, method analysis, and work measurement have long been recognized as essential to continued improvement in productivity; similarly, there was a perceived need for administrative and management practices emphasizing leadership rather than drivership, based on mutual recognition of a shared responsibility for the long-term success of any organization.

The material presented in this book is essentially a reprise of proven techniques aimed at practitioners who continue to search for the one best way, which in truth can exist only momentarily. Changing conditions require continuous effort to reevaluate,