WORK METHODS and MEASUREMENT for MANAGEMENT

Leonard A. Doty

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To Lucy
and to Paul, Stephen, Karen, Brian, Debora, Keith, and David

P · R · E · F · A · C · E

Managers of manufacturing enterprises need to have knowledge of, and abilities in, many diverse functions. Central to these is some kind of informational feedback and control. Information feedback keeps managers apprised of the condition of the firm or operation, and control tells them the condition in relation to a goal or standard. Once the information is available in meaningful form and compared to a standard, managers can take corrective action to bring the operation back into control (back to where it ought to be).

This book examines some of the central functions of manufacturing management—the critical functions that provide information and control. Due to the basic standard setting and control activities of industrial engineering, that function is used as the central theme of the text. Other informational feedback and control functions that impinge upon and interact with industrial engineering are also discussed.

The book opens with a general description and history of motion and time study. Next the procedures and charts used in analyzing work methods are discussed (Chapters 2 and 3). Chapter 3 concentrates on the use of motion study to reduce costs. Chapters 4 and 5 explain how time standards are set and how they are used to control labor costs. Chapter 6 examines automatic processes as control functions, along with computers and robotics, while Chapter 7 discusses another cost-reduction scheme—value engineering—which concentrates on defining the value, or worth, of product characteristics so that the essential functions can be supplied at the least cost. Motivation and job enrichment, the modern attempt to increase the quality of work life, are discussed in Chapter 8. The organization and operation of an industrial engineering function is outlined in Chapter 9. Finally, Chapter 10 on safety and product liability is included at the end of the text. Safety and product liability have become so important, with substantial effects on company and manufacturing policy and procedures, that accrediting societies (ABET, Accreditation Board for Engineering and Technology, for instance) are now demanding their inclusion in all engineering curricula.

The style and procedures of the book have been kept simple. Only a thorough grounding in algebra is needed; no calculus is used. Each chapter opens with a simple statement about the overall goal followed by a list of specific objectives. The remainder of the chapter is divided into sections, each of which discusses a particular objective in detail. Each section is numbered to correspond to the objective it addresses. For instance, Section 1.1 discusses Objective 1 of Chapter one; Section 5.6 addresses Objective 6 of Chapter five, and so on. This presentation format was chosen because it facilitates good thought organization and good thought flow (from objective to objective); and because it helps to focus each discussion on a particular concept and exclude extraneous and unnecessary detail.

This book is intended for use as a beginning textbook on the industrial engineering or industrial management function. A secondary purpose is to provide a summary reference of the important control functions of manufacturing management for the practicing industrial engineer, methods and standards engineer, and/or production supervisor. Due to the nature of the second purpose (as it must be rather comprehensive in its coverage), the teacher or student might find more subjects covered in this text than normally would be required in most beginning courses. Some of the subjects in the text—such as cost accounting, safety, automation, etc.—almost certainly will be covered in other courses in the curriculum. The problem is that different curricula will contain different subjects, depending on their individual purposes and objectives. The decision as to which subjects to leave in the course and which to omit must be made by the instructor.

Chapters 1 through 4, 8, and 9 should form the foundation of any methods and standards course. In addition, many subjects from Chapters 5 and 6 should be included, depending on what is taught in other courses in the curriculum and the objectives. Value engineering, Chapter 7, is now required in all government contracts and, if not taught elsewhere, could be included here. Safety, Chapter 10, is now required by most engineering accrediting agencies. Since most engineering curricula do not have room for a full course on safety, including this chapter in the course would seem an excellent way of satisfying this accrediting requirement.

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Leonard A. Doty

C · O · N · T · E · N · T · S

Work Methods and Measurement for Management

C · H · A · P · T · E · R 1

Introduction

The purpose of this chapter is to introduce the subjects of methods design and work measurement and to present a brief history of their developments.

O · B · J · E · C · T · I · V · E · S

1. Explain the historical development of time study and scientific management.
2. Explain the historical development of motion study.
3. Define methods design and work measurement, and explain how the two are combined into one system.
4. List and briefly explain the tools and procedures of methods design and work measurement.

1·1 HISTORY OF TIME STUDY

Time study had its beginning in the 1880s at the Midvale Steel Company when a young engineer named Frederick W. Taylor began to experiment with work methods. He soon found that they could not be left to the whim of the worker, no matter how experienced he was. Work methods, said Taylor, must be engineered, that is, designed in a systematic way. One of his earliest experiments was with the shoveling of coal and iron ore. Every worker was allowed to use his own type and size of shovel and his own method of shoveling. Taylor was able to prove that only one type and size of shovel was best for all workers. His experiment also showed that only one method (series of motions) was the most efficient. At the end of the experiment he had reduced the shoveling crew from 500 to 140 men with an annual savings of $78,000. His experiments also proved that rest periods actually could increase production, and that rest should be engineered into the work methods.

In order to prove his allegations, Taylor invented a method of measuring the time to do the job. This *time study* method, as it was called, started by breaking the job down into its component elements (an element was the smallest series of related motions that was reasonable, and possible, to time), timing each element, and adding up the total for a job "standard time." Two advantages to this method were immediately apparent: First, a careful, engineered method (if adhered to by each operator) would result in the lowest operating cost for the job—the company would save money. Second, if each method were carefully described and each operator required to use that method, management could then predict in advance the time it ought to take to do a job. Cost estimation, bidding, planning, and a host of other managemental responsibilities were immediately simplified.

Taylor went on to establish what he called *scientific management*. His purpose was to substitute scientific investigation and analysis for individual judgment and opinion in the management of an enterprise. Until Taylor's time, it was thought that the management of large groups of people was an art into which a person had to be born. Taylor changed this kind of thinking by proving that management is a skill that can be transferred from person to person: It can be taught.

There are four parts to Taylor's scientific management theory (Taylor, 1929, p. 36).

> *First.* The development of a science for each element of a man's work, thereby replacing the old rule-of-thumb methods.
> *Second.* The selection of the best worker for each particular task and then training, teaching, and developing the worker in place of the former practice of allowing the worker to select his own task and train himself as best he could.
> *Third.* The development of a spirit of hearty cooperation between the man-

> agement and the men in the carrying on of the activities in accordance with the principles of the developing science.
> *Fourth.* The division of the work into almost equal shares between the management and the workers, each department taking over the work for which it is better fitted; instead of the former condition, in which almost all of the work and the greater part of the responsibility were thrown on the men.

Taylor was a true scientist who made many noteworthy contributions to the art of management. In addition to time study and scientific management, he invented tool steel, derived a formula that clearly and concisely described the interrelationships of the variables involved in the cutting of steel, originated the functional type of organizational structure, and became one of the very first management consultants (advising management on the practical aspects of his scientific management theory).

An unfortunate side effect to the application of Taylor's theories was the schism that developed between management and labor. Although Taylor clearly espoused a cooperative attitude between management and labor, what actually occurred was quite different. The fact that management now assumed the prerogative to define the method and tools left labor with no real creative responsibilities. All labor could do under Taylor's "scientific management" was to obey management's directives. In effect, this made most laboring jobs less inspiring and more demeaning than ever.

In addition, Taylor's theories were frequently imposed (at least at first) on the workers without adequate explanation and with brutal disregard for their feelings. Although Taylor clearly taught that workers should be rewarded for their cooperation in applying the new theories (he frequently paid 60 percent over regular day rates to workers who achieved his "standard time"), many early users of his methods began the practice of requiring workers to achieve the new rates with little or no extra pay. Finally, early "efficiency experts," in applying Taylor's principles, would incorrectly and unfairly require a faster and faster pace without adequate justification. Since management, in effect, had the power of life and death over the workers (layoffs often meant starvation for worker and family in those days), labor was left with no alternative but to band together against the "common enemy." Thus the cooperation envisioned by Taylor often degenerated into management/labor strife that continues to this day.

1·2 HISTORY OF MOTION STUDY

In the early 1900s, shortly after Taylor, the husband and wife team of Frank and Lillian Gilbreth invented another management analysis tool they called *motion study.* Motion study is quite similar to time study's elemental breakdown in that the job is divided into its component parts. However, there is one important difference, that makes motion study a major management tool in its own right. The elemental breakdown of time study is for the purpose of timing an individual job and is, therefore, applicable to that job only. Motion study, on the other hand, analyzes fundamental motions that are applicable to all similar tasks. Motion study has much wider and more general applications than does time study's element breakdown. The Gilbreths were able to show that most, if not all, jobs are performed by different combinations of seventeen fundamental motions called *therbligs* (explained fully in Chapter 2). Each of these fundamental motions is the same for each job or task, whenever used.

Motion study initially began with Frank Gilbreth observing the bricklaying trade. Frank noticed that three different sets of motions at different times and under different circumstances, often were used by the same bricklayer. One set would be used during the learning process, an entirely different set by experienced journeymen, and another when training a new apprentice. Frank reasoned that a great deal of the learning process might be shortened if some way could be found to train the novice apprentice in the best method right at the start. Breaking the job into its component motions (the therbligs) turned out to be the answer. For years Frank believed that an analysis of motion was all that was needed to ensure an efficient operation. However, he was finally forced to include time study in his methods. He discovered that management needs a standard for planning purposes and the workers need one for comparison of actual accomplishment (how close did I come to the standard? for instance). Thus the concepts of time study and motion study were combined.

The Gilbreths were also excellent scientists, every bit as accomplished as Taylor. They invented *micromotion study*, the use of motion pictures keyed to a timing device to analyze and time a job; the *cyclegraph*, the use of lights on moving members that were photographed to obtain motion patterns; and the *chronocyclegraph*, a keyed timing device connected to the cyclegraph. They established a laboratory in their home for experimentation into the various aspects of motion analysis, and often involved the entire family in the studies. Their twelve children were used as a real-life laboratory for motion study. The children were timed and their motions studied as they performed various household duties.

Upon marriage, the Gilbreths had agreed to have, and raise, one dozen children. Unfortunately, Frank Gilbreth died of a heart attack shortly after the twelfth child was born, leaving the entire brood and the couple's thriving industrial engineering consulting business to his wife Lillian. She successfully handled the business even in the face of male resistance, having been denied membership in the Society of Mechanical Engineers because she was a woman. Lillian eventually joined the faculty of Purdue University where she taught and lectured until well past ninety years of age. (For a more complete treatment of the Gilbreth's family life, see the book *Cheaper by the Dozen*, a best seller authored by two of the older children.)

Both Frank and Lillian Gilbreth were college graduates. Frank was a graduate in mechanical engineering and Lillian in psychology. She later returned to school and earned a Ph.D. in mechanical engineering, but it was her psychological training and basic personality that caused her to be more people oriented than most of her associates, all of them male. Time after time she influenced the team toward a more humane methods design. In this respect, Lillian was a forerunner of the motivational theorists, job enrichment procedures, and supportive and cooperative management schemes of modern methods design.

1·3 DEFINITIONS

Although the term *time study* is frequently used interchangeably with *work measurement*, it is technically inaccurate. Time study, though important, is just one of a group of work measurement techniques. Work measurement determines the time frame for a job. This desired, or engineered, time is called *standard time* and is the time used for planning and for comparative purposes.

One reason for the many different types of work measurement techniques is that different methods are needed for different types of jobs. For instance, a highly specialized and rather time-consuming technique might be used to time an ongoing production job, while jobs of short duration would be timed by a more casual, general, system. The specialized technique would be more costly to use but would give a much more accurate and precise measurement. Such precision would be much more desirable, and the extra cost much more easily absorbed, for large production runs rather than for small occasional jobs. It would serve no useful purpose, for instance, to spend $1,000 extra for precise measurement of an intermittently run job if the savings realized by the extra precision were only $500.

The type of study to be used would be controlled by the intensity of five factors: First would be the life of the job; how long will it last before it is replaced by another product? Second is the extensiveness of the job; how many hours of the day, week, or month will the job run? Third is the labor intensity; what percent is labor time compared to the total time? Fourth is capital investment; how much will the machines, tools, etc., cost? Fifth is the time and cost of the analysis.

Methods design is a more descriptive and inclusive term than motion study, although the two terms are almost always used interchangeably by methods and work measurement professionals. Another term that is often used interchangeably with methods design is *methods analysis*. Once again, methods design is a more inclusive term, as methods analysis refers more to the process of determining meaningful relationships and is the activity that usually precedes the actual design. However, the connotational differences among these terms are slight and usually are ignored in actual practice. Such will be the case in this book. Motion study, methods analysis, and methods design all will be assumed to mean the same thing. Since methods design is more descriptive and more complete, it will be the preferred term.

Methods design is defined as the systematic design of work systems. It is a description of the step-by-step procedure needed to do a job most efficiently—usually meaning least cost. The number of steps, the order of the steps, and the difficulty (or simplicity) of the steps are all important in order to properly minimize the time and cost. Many charts, graphs, mathematical models, and specialized procedures are available to assist in the analysis used to determine the "best method."

In actual practice it is difficult to separate methods design and work measurement. In designing work methods it is necessary to have some knowledge of the various times involved in order to judge the efficiency of the method and to know whether the design is indeed the "best method." Conversely, proper work measurement requires well-defined motion patterns. An explanation of work methods design usually requires terms and concepts from work measurement, and work measurement explanations almost always require terms and concepts from methods design. Therefore, in modern usage the two systems are almost always combined as if they were one.

When the two concepts—methods design and work measurement—are combined, the definition must be expanded. There are four parts to this more formal definition: First, the preferred method must be developed. Second, the method must be standardized; a written standard practice must be recorded. Third, the job must be timed; a standard time must be determined. Fourth, the worker must be trained. All four of these steps must be completed properly when conducting a full-fledged methods design and work measurement project.

The preferred method is determined by using a systematic approach utilizing the scientific method. The problem is defined and analyzed, solutions synthesized, and recommendations determined and evaluated. It is important at the start of a methods design to set clearly defined, concise, measurable objectives. An objective might be to design a least-cost system (most methods designs are of this nature), a least-time system (sometimes the fastest method does not give the least cost), or a safest possible method (nuclear power plants, for instance).

In standardizing the method, the job is broken down into its component tasks. Each task is detailed, with the required set of motions listed in order of occurrence and explained. All aspects of the job are described and specified carefully, including materials, tools, equipment, and working conditions. These specifications are preserved in a written record called a *written standard practice* (WSP).

To determine the standard time, the assumption is that a well-qualified worker who is well trained to the method is doing the work. Many different methods can be used, including time study (most used), predetermined time systems (sometimes called *motion-time data*), work sampling, standard data, and even some form of educated guess. Standard times start with an actual recorded time, which is then adjusted to account for the observed work pace (predetermined systems do not use this step). *Normal time*, as it is called, is then increased by adding allowances for personal time, delays, and fatigue to get the standard time.