Chapter 1

Introduction to Work Measurement

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1 Introduction

Industrial engineering focuses on optimizing complex processes or systems. It involves the integration of people, machines, materials, information, and energy to produce a product or provide a service efficiently and effectively. The nature of work in this field includes process design, systems analysis, operations management, quality control, and ergonomics.

The study of work and the Industrial Revolution provide a historical context and foundational principles that shape modern industrial practices. Work systems focus on the design, analysis, and improvement of work methods on systems. It involves examining how tasks are performed and seeking ways to enhance efficiency, reduce waste, and improve productivity.

The concept of a minimum wage emerged in response to the exploitation of workers during the Industrial Revolution. Workers often faced extremely low pay, long hours, and poor working conditions. The first modern minimum wage laws were enacted in Australia and New Zealand in the late 19th and early 20th centuries. New Zealand's Industrial Conciliation and Arbitration Act of 1894 and Australia's New South Wales Minimum Wage Act of 1907 set the precedent. The Fair Labor Standards Act of 1938 established the first federal minimum wage in the U.S., setting a standard for fair pay and working hours.

The Industrial Revolution began in Great Britain around 1770 and spread to other parts of the world. Before the Industrial Revolution, goods were produced in small workshops or homes, often using hand tools. Adam Smith’s “Wealth of Nations,” published in 1776, discussed the concept of labor specialization in his seminal work, emphasizing the efficiency gains from dividing labor into specific tasks. Specialization allows workers to become highly skilled at specific tasks, leading to faster and more efficient production. Specialization can improve the quality of work, as workers develop expertise in their specific tasks. Focused expertise can lead to innovation and improvements in techniques and processes. Pioneered by Henry Ford, the assembly line is a practical application of labor specialization, where each worker performs a specific task in the production process. Factories began to centralize production under one roof, allowing for greater control and efficiency. The introduction of machinery and mechanization drastically increased production capacity and efficiency. The factory system utilized labor specialization, assigning workers specific tasks to optimize production. Factories led to the growth of cities as people moved from rural areas to urban centers for work. Factory work often involved long hours, low pay, and poor working conditions, leading to the rise of labor unions and movements for workers' rights.

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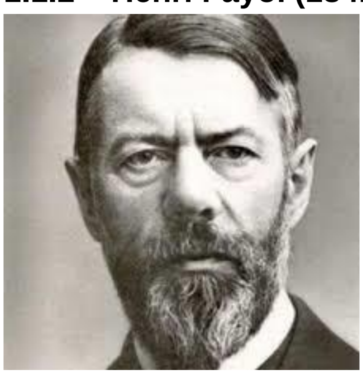
1.1 Historical Figures in Work Measurement[1,2]

1.1.1 Eli Whitney (1765-1825)

Eli Whitney was born in Westborough, MA in 1765 and graduated from Yale College in 1792 and is known for inventing the cotton gin in 1793 and popularizing the concept of interchangeable parts after obtaining a contract to produce 10,000 muskets from the U.S. government, which revolutionized manufacturing processes by allowing for mass production and easier assembly and repair of products. His achievement was made possible by the special machine tools, fixtures, and gauges that he developed in his Connecticut factory. This required components that could be made accurately enough to permit parts assembly without fitting. Interchangeable parts were a prerequisite for mass production of assembled products.

1.1.2 Henri Fayol (1841-1925)



The line and staff organization model emerged from classical management theories developed in the late 19th and early 20th centuries. Fayol, born in Istanbul, Turkey in 1841 and a graduate of Ecole des Mines de Saint-Étienne in 1860, was a French mining engineer and management theorist, and one of the early proponents of the line and staff organizational structure. His 1916 publication of *General and Industrial Management*[3] was viewed as a landmark in management thought since it provided the first comprehensive theory of management. His view of management problems was from the board of directors down. Line roles involve direct, core activities related to the primary

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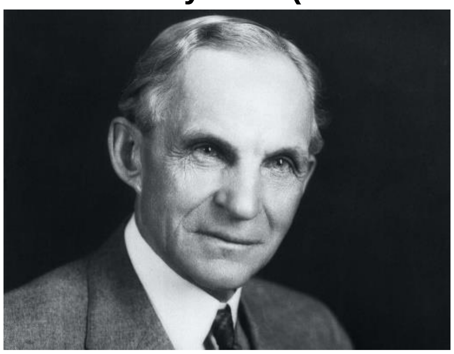
mission of the organization (i.e., production, sales). Line managers have direct authority over these activities and are responsible for achieving organizational goals. Staff roles provide specialized support and expertise to assist line functions (i.e., HR, legal, accounting). Staff managers do not have direct authority over line activities but offer advice, analysis, and services, helping line managers make informed decisions. The line and staff structure establishes a clear hierarchy and division of responsibilities, improving organizational efficiency and accountability. By combining direct authority with specialized support, organizations can respond more effectively to changes and challenges. Fayol was a strong proponent of planning as an important and essential factor of management since it enables one to assess the future and make provision for it.

1.1.3 Henry Ford (1863-1947)



Henry Ford was born in Springwells Township, MI in 1863 and later founded the Ford Motor Company. He is credited with making automobiles affordable for middle-class Americans. To meet the mass demand for consumer products in the late 1800s and early 1900s, more efficient production methods, such as mass production, were required. Ford revolutionized the automobile industry with the introduction of the moving assembly line, significantly reducing production time and costs. His Model T became the first affordable car for the masses.

1.1.4 Frederick Winslow Taylor (1856-1915)

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Frederick Taylor was born in the Germantown section of Philadelphia, PA in 1856. Taylor began his career at Midvale Steel Company in Philadelphia in 1878 as worked as a gang boss, assistant foreman, machine shop foreman, master mechanic, chief draftsman, and chief engineer. He also organized the managements at Bethlehem Steel Company and Cramps Shipbuilding Company, in addition to Midvale Steel Company. Widely recognized as the father of scientific management, Taylor introduced methods to analyze and optimize workflows. His principles emphasized standardizing work processes, selecting the right workers, training, and using time studies to set performance standards. Unlike Fayol, whose perspective of management problems was from the board of directors down, Taylor's perspective of management problems was from the shop floor. In 1900, Taylor received a personal gold medal from the Paris Exposition for his invention of the Taylor-White process for treating modern high-speed tools. He held nearly 100 patents and published 5 books in his lifetime.

Two famous experiments were conducted at Bethlehem: (1) the shoveling experiment, and (2) pig iron handling experiment.

Taylor's goal in the ***shoveling experiment*** was to determine the optimal way for workers to shovel materials, maximizing efficiency and minimizing fatigue. He observed that each yard worker brought his own shovel to work, and the shovels were all different types and sizes. The workers were required to shovel various materials in the yard, such as coal, iron ore, and ashes. Because the densities of these materials differed, it meant that the weight per shovelful varied significantly. Taylor and his team hypothesized that there was an optimal load size that a worker could shovel without becoming excessively fatigued. They experimented with different shovel designs and sizes to find the most efficient one. Taylor conducted time and motion studies to measure the amount of time and effort required to shovel different amounts of material with various types of shovels. Through this experimentation with the workers, he determined that different-sized shovels should be used for the different materials, which required different shovel designs to maintain the optimal load size. For example, lighter materials like ash needed larger shovels, while heavier materials like ore required smaller shovels. Taylor discovered that the optimal load size for a shovel was around 21 pounds. Shoveling this amount allowed workers to maintain a steady pace without becoming overly fatigued. This load weight maximized the amount of work that could be accomplished each day by a worker and minimized the costs to the company. By standardizing shovel sizes and optimizing the shoveling method, Taylor demonstrated significant increases in worker productivity and reductions in fatigue. The experiment highlighted the benefits of designing tools and work methods that match the capabilities of workers, leading to improved efficiency and reduced physical strain.

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Pig iron is the iron tapped from a blast furnace, which contains impurities and must be subsequently refined to make cast iron and steel. Taylor’s goal in the ***pig iron handling experiment*** was to improve the efficiency of handling pig iron at the Bethlehem Steel Company by increasing productivity while reducing the physical strain on workers. Taylor believed that the yard workers who loaded pig iron from the storage yard into freight cars were not using the best method. The workers seemed to work too hard and then had to rest for too long to recover from the physical exertion. Taylor selected a group of strong workers and trained them in the optimal methods for handling pig iron. Their daily wage in 1898 was $1.15 and they averaged 12.5 tons per day. Taylor confronted one of the men (identified as Schmidt, a fictional name given by Taylor) and offered him the opportunity to earn $1.85 per day if he followed Taylor’s instructions on how to perform the work. Taylor identified the most efficient way to handle pig iron, which included specific instructions on lifting techniques, carrying distances, the rhythm of work, and rest periods. He discovered that introducing regular rest breaks was essential to maintain high productivity and prevent fatigue. Detailed time and motion studies were conducted to analyze the movements and methods used by workers to load and unload pig iron from rail cars. He established a work-rest cycle where workers handled pig iron for a specified period and then took a short rest. By implementing the optimized work methods and work-rest cycles, Taylor was able to increase the amount of pig iron handled by each worker from around 12.5 tons per day to over 47 tons per day. Other workers were eager to sign on for the higher wages. The standardized methods and regular rest breaks helped reduce worker fatigue and the risk of injury. The pig iron handling experiments reinforced Taylor's principles of scientific management, demonstrating the effectiveness of systematic analysis and optimization of work methods. The experiment also highlighted the importance of selecting the right workers for specific tasks and training them in optimal work methods to maximize efficiency and productivity.

Taylor’s Principles of Scientific Management

The main objective of Taylor’s *Principles of Scientific Management*[4] book, published in 1911, was to improve economic efficiency, and in particular, labor productivity. It is one of the earliest attempts to apply science to the engineering of processes to management. Taylor’s four principles are:

1. **Develop a Science for Each Element of Work by the means of Time and Motion Study**: Analyze tasks to determine the most efficient way to perform them.
2. **Scientifically Select, Train, and Develop Workers**: Choose the right person for the job and provide proper training.

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3. **Cooperate with Workers**: Ensure that the work is carried out according to the developed science and by providing some incentive to the worker.

4. **Complete redivision of the work**: Management takes responsibility for planning, while workers execute the tasks.

1.1.5 Frank Gilbreth (1868-1924)

Frank Gilbreth, born in Fairfield, ME in 1868, was an American engineer, management consultant, and author. He is best remembered for his pioneering research on analyzing and simplifying manual work. Known as the “father of motion study,” he developed two important theories in scientific management: (1) that all manual work was composed of 17 basic motion elements that he called “therbligs” (his last name spelled backwards, mostly), and (2) the principle that there is “one best way” to perform a given task. He was able to apply the principles of time and motion study to the labor of construction workers and other industrial employees to increase their efficiency and output.

1.1.6 Lillian Gilbreth (1878-1972)

Lillian Gilbreth was born in Oakland, CA in 1978 and earned bachelor’s and master’s degrees at the University of California, Berkeley and earned a PhD degree at Brown University in 1915, a rarity for women at the time. Married to Frank Gilbreth and a teacher and psychologist by trade, Lillian Gilbreth collaborated with Frank Gilbreth in his research on motion study by contributing a synthesis of psychology and scientific management on

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work to increase worker efficiency, which later became known as industrial and organizational psychology. After Frank’s premature passing in 1924, Lillian assumed the presidency of their time and motion study consulting firm and continued working as a researcher and lecturer while advocating time and motion study in her work.

1.1.7 Harold B. Maynard (1902-1975)

Harold Maynard, born in Northampton, MA in 1902 and later graduated from Cornell University in 1923, is one of the most important figures in the development of predetermined motion time systems. He is largely responsible for the Methods-Time Measurement (MTM) system and was the CEO of his world-famous consulting firm, H. B. Maynard and Company, based in Pittsburgh, Pennsylvania. The company still exists and bears his name to this day. MTM became the most successful and widely used first-level PMTS after its release in 1948. The MTM database of motion elements was used in the development of many higher-level systems in the MTM family to satisfy various user needs. Several MTM systems have been developed for specific work situations such as clerical activity and machine shop work. Second and third level systems, as well as computerized systems, have been developed to reduce the time required to determine time standards.

Kjell B. Zandin is largely responsible for the development of the Maynard Operation Sequence Technique (MOST). MOST is a predetermined motion time system that is used primarily in industrial settings to obtain the standard time in which a worker should perform a task. It focuses on grouping motions together into pre-defined activity sequence models, using table values to estimate total Time Measurement Units (TMUs), which are then converted into standard times. This resulted in the definition of three principal motion groups – General Move, Controlled Move, and Tool Use. MOST was first introduced in Sweden in 1972 and in the U.S. in 1974. It is one of the most widely used PMT systems.

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1.2 The Importance of Time

Time is a crucial factor in industrial engineering as it directly impacts productivity, costs, and efficiency. Time is important in work for several reasons: 1) time is the most frequently used measure of work, 2) most workers are paid according to the amount of time they work, 3) when workers are paid on an incentive plan, they earn their bonuses based on how much time they save relative to the standard time for a given task, and 4) labor and staffing requirements are based on workloads measured in units of time. Time standards are established to determine the amount of time required to complete a task under defined conditions.

Work measurement refers to a set of four techniques that are used to determine the time that an average worker is allowed to perform a task. These four techniques are:

1. *Direct time study*. Direct time study involves the direct observation of an employee, and is often video recorded, to identify distinct work elements that comprise a task. The observed time of each work element on each cycle is then recorded. Irregular and foreign elements may also be identified. Performance ratings for each work element are assigned by the time study analyst. An allowance time for personal time, fatigue, and delay is added to the sum of the normal times to derive the standard time to perform the task.

2. *Predetermined motion time systems*. MTM-1 and MOST are two of the most common PMTSs used in the world.

3. *Standard data systems*. A compilation of normal time values for work elements used in tasks that are performed in each facility creates a standard data system.

4. Work sampling. The work sampling technique is used to determine the proportion of time workers spend in different activities during the time study period.

1.3 How to Determine Time Standards[5]

Most workers are paid for the time they work. A common work shift in the U.S. is eight hours and workers are paid an hourly rate for those eight hours. Given this, management might be interested in knowing how much work was accomplished during an eight-hour shift and whether the worker has done a fair day's work in exchange for the wages earned.

The standard time for a given task is the amount of time that a trained worker following standard procedures and working at a normal pace, including a time allowance for personal time, fatigue, and delay, should complete a task.

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Time standards serve important functions in an organization:

1. They help to define “a fair day’s work.” That is, when the product of the quantity of work units produced by a worker is multiplied by their respective standard times per unit equals the number of hours in the shift, then the worker has accomplished a fair day’s work.
2. Time standards allow for the computation of required staffing and equipment resources needed to accomplish the workload.
3. Alternative methods can be compared objectively with time standards.
4. They can be used to determine wage incentives and for evaluating worker performance.
5. Time standards can be used for production planning and scheduling purposes, cost estimating, and materials requirements.

1.3.1 Methods Used to Determine Time Standards

The three primary methods for determining time standards are: 1) estimating, 2) historical records, and 3) work measurement techniques.

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Figure 1.1 illustrates methods used to determine time standards.

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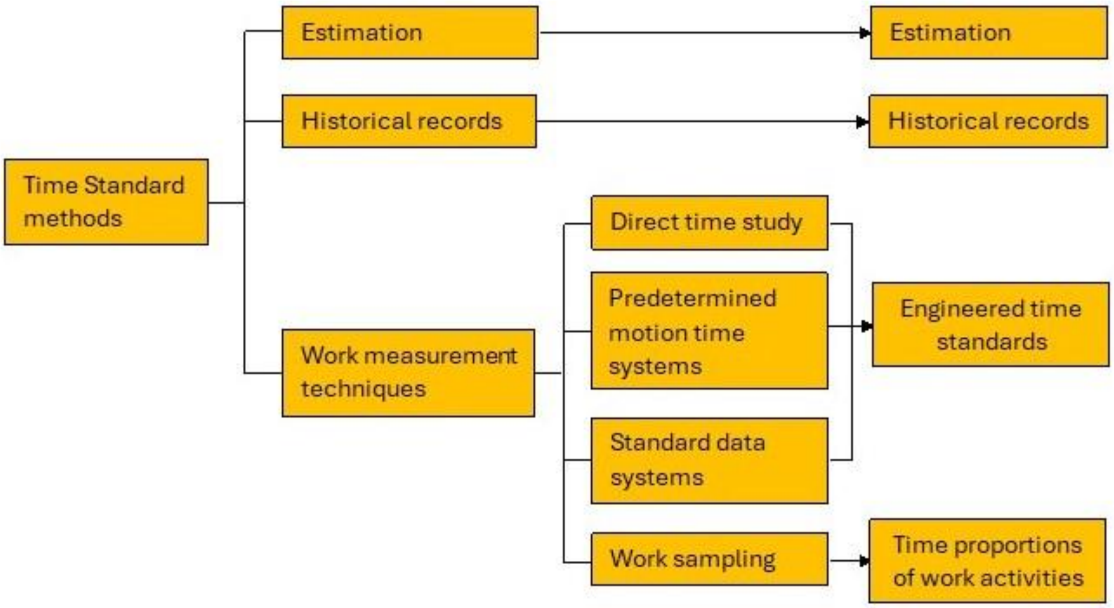

Figure 1.1. Time standard methods.

With estimation, an expert familiar with jobs performed in a department is consulted for how much time should be allowed for setups and run time for a given job. Since no documentation is involved, this method is the least reliable of those mentioned.

In contrast, historical records provide documentation of previous production runs from which to draw conclusions. Whether the documentation occurs manually (i.e., production time sheets) or electronically (i.e., real-time computerized data collection), the average time to produce a unit of product can be calculated. Because historical records reflect previous actual production times, it is an improvement over estimation.

Whereas direct time studies, predetermined motion time systems, and standard data systems produce engineered time standards, work sampling measures the proportion of time workers spend in multiple activities.

1.3.2 Work Measurement Techniques

Work is an activity in which one exerts physical and mental effort to accomplish a given task or perform a duty. A work element is defined as a series of work activities that are logically grouped together because they have a unified function in the task. A task consists of work elements and each work element consists of basic motion elements. Basic motion elements are actuations of the limbs and other body parts while engaging in performing the task. Basic productive work content refers to the theoretical minimum amount of work required to accomplish the task. As a physical entity, a work system is a system consisting of humans, information, and equipment that is designed to perform useful work. The various work measurement techniques measure work at different levels

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of the task hierarchy. Figure 1.2 illustrates the relationships between task hierarchy level and work measurement techniques.

Task Hierarchy Level		Work Measurement Technique
Job level		
Task level	→	Work sampling
Work element level	→	Direct time study, standard data systems
Basic motion element level	→	Predetermined motion time systems

Figure 1.2. Mapping between task hierarchy level and work measurement technique.

***Direct Time Study*.** Direct time study involves the direct observation of a task that is broken down into separate and distinct work elements using a timing device, such as a stopwatch or the stopwatch feature on a smartphone. Each work element has a specific starting and stopping point that is determined by the time study analyst. The difference between the starting and stopping times becomes the observed time to perform each work element and is documented on a time study worksheet. Observed times are recorded for each work element for each cycle in the time study. The time study analyst assigns a performance rating for each work element (or each observed time or the job as a whole) that reflects the analyst's best judgment of the pace of the worker in the performance of that work element. The observed time is then multiplied by the performance rating to yield the normal time for that work element.

$$T_n = T_{obs}(PR) \tag{1.1}$$

where Tn = normal time (the time required by a worker working at 100% normal pace for one cycle), sec or min; Tobs = observed time, sec or min; PR = performance rating (typically given as a percentage but converted to a decimal number for calculation purposes).

An allowance factor for P, F, and D is multiplied by the total normal time to yield the allowance time. Finally, the sum of the total normal time plus the allowance time yields the total standard time for the task.

$$T_{std} = T_n\left(1 + A_{pfd}\right) \tag{1.2}$$

where Tstd = standard time, sec or min; Tn = normal time, sec or min; Apfd = allowance factor for personal time, fatigue, and delays (PFD).

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Predetermined Motion Time Systems (PMTS). A predetermined motion time system employs a database of basic motion elements (i.e., therbligs), such as reach, grasp, move, and release that are common to nearly all manual tasks. Accompanying each motion element is a set of normal times, in time measurement units (TMUs), whose values depend on the conditions under which the basic motion element was performed. For example, the normal time for a reach depends on the distance reached. Naturally, longer distances take more time. The normal time for a move depends on both the distance moved and the weight of the object being moved. The sum of the TMUs multiplied by 0.036 sec/TMU yields the total normal time in sec. The allowance time can be obtained by multiplying the total normal time by the allowance factor for P, F, and D. Finally, the standard time is obtained by summing the total normal time plus the allowance time.

Two significant advantages of PMTS are: (1) performance ratings are not required since the table values are already "normalized", and (2) the table values can be used to estimate the standard time for a task before production.

Standard Data Systems. A standard data system (SDS) employs a compilation of normal time values for work elements used in tasks that are performed in each facility. These normal times form a database that is used to compute time standards for tasks. A principal advantage of SDS is that a time standard can be calculated before the job is in production provided the work elements have already been defined in the SDS.

The normal times for SDS may come from direct time studies, PMTS data, work sampling data, or historical time records. Large amounts of data are usually required to create a database. Work elements may be performed under different work variables, which may affect their normal time values. The normal time for a given work element is a function of the work variable(s), and this functionality must be included in the database in the form of tables, charts, graphs, or mathematical equations.

To properly use a standard data system, the time study analyst must first identify, and then combine, the work elements that comprise the task with the values of the work variables for each work element. The analyst then refers to the database to find the normal times for each work element. The sum of the work element normal times determines the total normal time for the task. An allowance time is added to the total normal time to yield the standard time for the task.

Work Sampling. Work sampling uses random observations to study work situations and determine the proportion of time each worker spends in different major categorical activities. Required sample sizes can be determined from preliminary data to estimate the number of samples that are required to estimate parameter values and be within a certain degree of accuracy. The activities must be defined specifically for the work situation under

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study. In a production worker example, the worker may be setting up a machine, running a machine, performing minor maintenance, waiting on stock, help, or a supervisor, in a meeting or training session, on a break, and so on. The main objectives of a work sampling study is to determine either machine or worker utilization in a plant or to determine an appropriate allowance factor for use in direct time studies. A principal advantage of work sampling is that the time study analyst can observe several workers in a department at the same time. Two primary disadvantages are that work sampling is less precise than direct time study and it does not capture methods variation.

1.4 Requirements for Valid Time Standards

The time to perform a work cycle of any manual task depends on several factors, such as the worker's physical size, strength, and mental abilities; the worker's pace, the work method used (i.e., hand and body motions, tooling requirements, equipment, and the work environment), and the size, weight, and level of difficulty in producing the work unit.

To accurately determine the standard time for a task, the worker must engage in the following, as illustrated in Figure 1.3:

1. The task must be performed by an ***average worker***.
2. The worker's pace represents ***standard performance***.
3. The worker follows a ***standard method***.
4. The task is performed on a ***standard work unit*** that is defined pre- and post-processing.

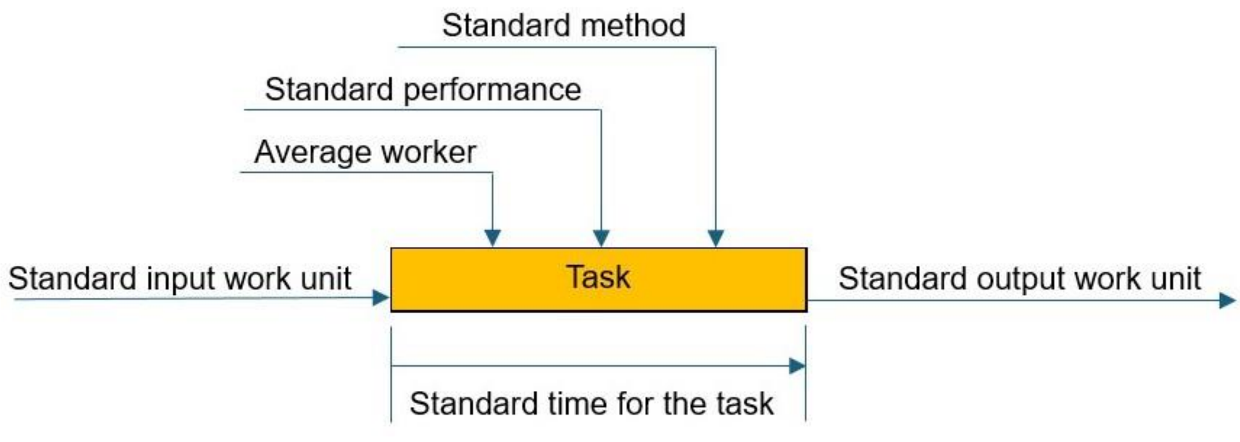

Figure 1.3. Inputs for computing standard time for a task.

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Moreover, requirements for valid time standards include:

1. **Accuracy**: Time standards should be precise and reliable.
2. **Consistency**: The same standards should be applicable across different workers and conditions.
3. **Fairness**: Standards should be attainable by a trained worker under normal working conditions.

1.4.1 Relative Accuracy of Time Study Methods

The relative accuracies of the various time study methods are illustrated in Figure 1.4.

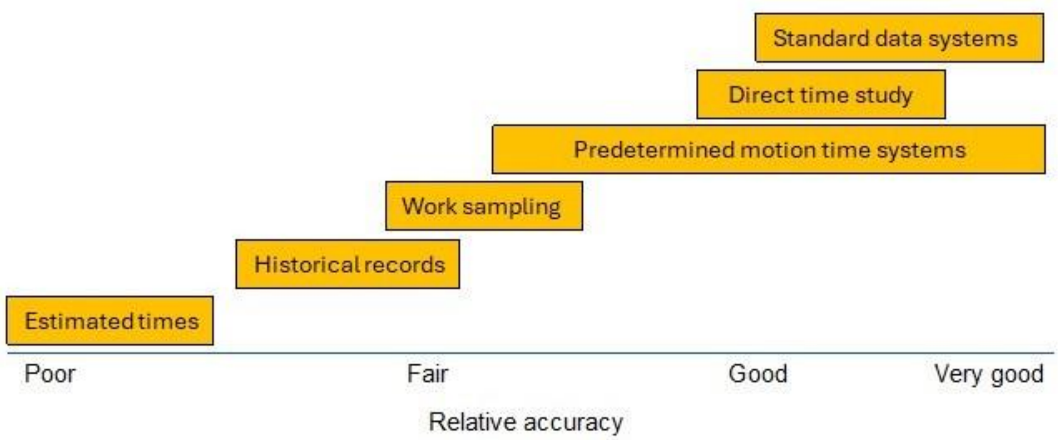

Figure 1.4. Relative accuracies of various time study methods.

Naturally, estimated times are the least accurate because estimates rely on an estimator's best judgment, which may not be very good, and are not based on actual data. Historical records provide an improvement of estimation because it relies on hard data on the average time to complete a previous order, although the accuracy of the data is sometimes questionable. Some data may be "ballpark" data or missing. Internal bias may be present in the data to falsely increase worker productivity or machine utilization. Historical records are based on measures of the work output, such as quantity produced, number of scrap units, delays, etc., and the start and stop times that were recorded for the output rather than an actual measurement of the work. Of the four remaining time study methods, work sampling is the least accurate due to statistical errors that may result from the sampling process, such as an inadequate sample size or an incorrect sample standard deviation, and the absence of any attempt to improve the method used in the task.

1.5 Productivity

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Productivity is an important metric in work systems and is defined as the ratio of outputs to inputs of a given production or service process. Productivity is how worker compensation can be increased without increasing the costs of the products and services produced. Excess nonproductive activities refer to the extra physical and mental activities by the worker that do not add value to the task. Three categories of excess nonproductive activities include 1) excess activities caused by poor design of the product or service, 2) excess activities caused by inefficient methods, poor work layout, and interruptions, and 3) excess activities caused by the human factor.

1.5.1 Labor Productivity Ratio

The most common productivity measure is labor productivity, which is the ratio of number of work units of output to labor hours of input as follows:

$$LPR = \frac{WU}{LH} \tag{1.3}$$

Where LPR = labor productivity ratio, WU = no. of work units of output, and LH = labor hours of input. For example, in the automotive industry, an appropriate output measure is the number of cars produced. In the paper mill industry, an appropriate output measure is the number of tons produced. Here, labor is one input factor that determines productivity. Other input factors include capital, technology, energy used, and raw materials.

Several difficulties may be encountered in calculating the labor productivity ratio from Eq. 1.3 above, such as:

1. *Nonhomogeneous output units*. For example, in the paper mill industry, tons may be an appropriate output measure, but this does not account for differences in paper grades, basis weights, paper color, strength properties, bleached vs. unbleached paper, etc.

2. *Multiple input factors*. Labor is not the only input factor in measuring productivity. Other important input factors that must be included are capital investment in machinery and equipment, technology, materials, and energy.

3. *Price and cost changes*. Over time, the cost of input factors (i.e., labor, materials, energy) and the price of output work units vary, often unpredictably. A company could suffer financial difficulties if increasing the costs of inputs is not offset by an increase in productivity.

4. *Product mix changes*. If the mix of expensive and inexpensive products changes every year, the labor productivity ratio is less meaningful.

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Example 1. Labor Productivity Ratio

A group of 10 workers in a certain month produced 9,000 units of output work 8 hr/day for 20 days. (a) What is the labor productivity ratio for this month? (b) In the next month, the same worker group produced 12,500 units but there were 21 workdays in the month and the size of the work group was reduced to 14 workers. What is the labor productivity ratio for this second month? (c) What is the labor productivity index using the first month as the baseline?

(a)

$$LPR = \frac{9{,}000\ units}{(10\ workers)(8\ hr/day)(20\ work\ days/mo)} = 5.625\ units/hr$$

(b)

$$LPR = \frac{12{,}500\ units}{(10\ workers)(8\ hr/day)(21\ work\ days/mo)} = 7.440\ units/hr$$

(c)

$$LPI = \frac{7.440\ units/hr}{5.625\ units/hr} = 1.322\ \times 100 = 132.2\%$$

∴ Productivity increased by 32.2% in Year 2 vs. Year 1.

Example 2. Labor Productivity Ratio

A military clothing company makes parkas for military contracts. The company just completed two contracts. The Navy contract was for 2,400 parkas and took 22 workers two weeks (40 hrs per week) to complete. The Army contract was for 6,200 parkas that were produced by 30 workers in three weeks. Which contract yielded more productive workers?

Navy contract:

$$LPR = \frac{2{,}400\ units}{(22\ workers)(40\ hrs/wk)(2\ weeks)} = 1.36\ units/hr$$

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Army contract:

$$LPR = \frac{6{,}200\ units}{(30\ workers)(40\ hrs/wk)(3\ weeks)} = 1.72\ units/hr$$

∴ The Army contract yielded more productive workers.

1.3.1 Labor Productivity Index

An alternative productivity measure is the labor productivity index, which compares the output/input ratio from a future year to the baseline year, as follows:

$$LPI = \frac{LPR_t}{LPR_b} \tag{1.4}$$

here LPI = labor productivity index, LPR_t = labor productivity ratio for a future time period, and LPR_b = labor productivity ratio for the baseline period.

Whereas the labor productivity ratio is defined as the output work units divided by the number of input labor hours, the labor productivity index is defined as the labor productivity ratio in some period of interest divided by the labor productivity ratio in a defined base year.

Example 3. Labor Productivity Index

If a factory produced 1,000 units in the current period and 800 units in the base period, what is the labor productivity index?

$$LPI = \frac{1{,}000\ units}{800\ units} = 1.25 \times 100 = 125\%$$

∴ Productivity increased by 25% in the current period vs. the base period.

1.4 Summary

The foundational work of Henri Fayol, Henry Ford, Frederick Taylor, the Gilbreths, and Horace Maynard has greatly contributed to the fields of work measurement and time and motion study. Time standards are crucial for productivity measurement, cost estimation, scheduling, and fair workload distribution. Various methods like time study, PMTS, standard data systems, and work sampling are used to establish these standards. The

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labor productivity ratio provides a snapshot of output per labor input, while the labor productivity index tracks productivity changes over time relative to a base period.

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