technical note

technical note four

JOB DESIGN AND WORK MEASUREMENT

The operations manager's job, by definition, deals with managing the personnel that create a firm's products and services. To say that this is a challenging job in today's complex environment is an understatement. The diversity of the workforce's cultural and educational background, coupled with frequent organization restructuring, calls for a much higher level of people management skills than has been required in even the recent past.

The objective in managing personnel is to obtain the highest productivity possible without sacrificing quality, service, or responsiveness. The operations manager uses job design techniques to structure the work so that it will meet both the physical and behavioral needs of the human worker. Work measurement methods are used to determine the most efficient means of performing a given task, as well as to set reasonable standards for performing it. People are motivated by many things, only one of which is financial reward. Operations managers can structure such rewards not only to motivate consistently high performance but also to reinforce the most important aspects of the job.

JOB DESIGN DECISIONS

Job design

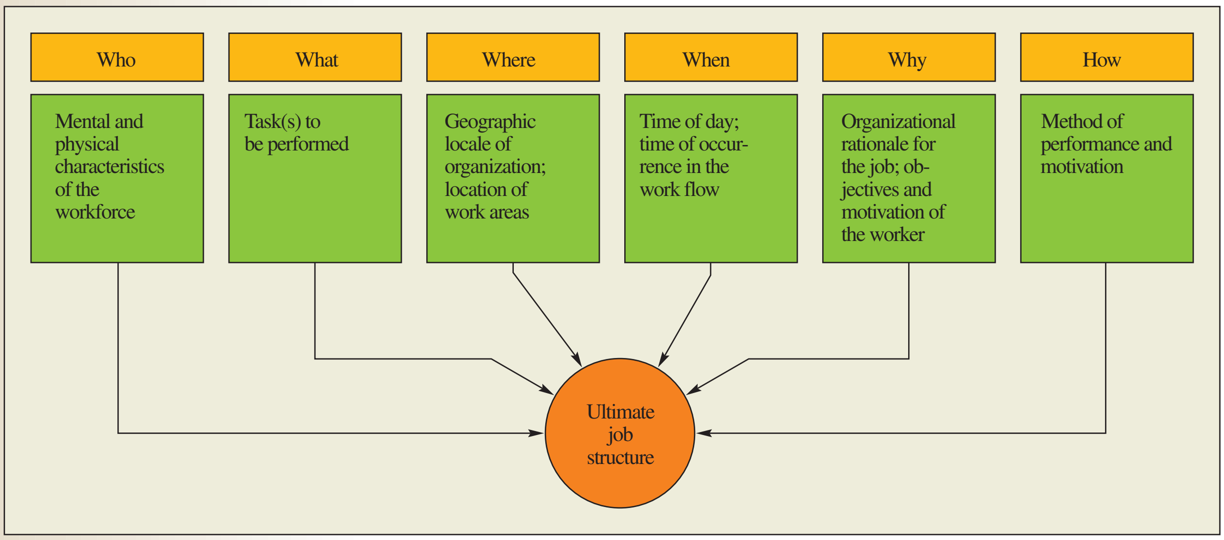
Job design may be defined as the function of specifying the work activities of an individual or group in an organizational setting. Its objective is to develop job structures that meet the requirements of the organization and its technology and that satisfy the jobholder's personal and individual requirements. Exhibit TN4.1 summarizes the decisions involved. These decisions are affected by the following trends:

1 **Quality control as part of the worker's job.** Now often referred to as "quality at the source" (see Chapter 7), quality control is linked with the concept of empowerment. *Empowerment,* in turn, refers to workers being given authority to stop a production line if there is a quality problem, or to give a customer an on-the-spot refund if service was not satisfactory.

2 **Cross-training workers to perform multiskilled jobs.** As companies downsize, the remaining workforce is expected to do more and different tasks.

3 **Employee involvement and team approaches to designing and organizing work.** This is a central feature in total quality management (TQM) and continuous improvement efforts. In fact, it is safe to say that virtually all TQM programs are team based.

EXHIBIT TN4.1 Job Design Decisions



4 **"Informating" ordinary workers through e-mail and the Internet, thereby expanding the nature of their work and their ability to do it.** In this context, informating is more than just automating work—it is revising work's fundamental structure. Northeast Utilities' computer system, for example, can pinpoint a problem in a service area before the customer service representative answers the phone. The rep uses the computer to troubleshoot serious problems, to weigh probabilities that other customers in the area have been affected, and to dispatch repair crews before other calls are even received.

5 **Extensive use of temporary workers.** Manpower, a company specializing in providing temporary employees, has over 1.9 million temporary employees worldwide on its payroll.

6 **Automation of heavy manual work.** Examples abound in both services (one-person trash pickup trucks) and manufacturing (robot spray painting on auto lines). These changes are driven by safety regulations as well as economics and personnel reasons.

7 **Most important of all, organizational commitment to providing meaningful and rewarding jobs for all employees.** Companies featured on *Fortune* magazine's "100 Best Companies to Work For" use creative means to keep employees satisfied, and offer generous severance and compassion when cuts must be made (see www.fortune.com for the current list of companies).

BEHAVIORAL CONSIDERATIONS IN JOB DESIGN

DEGREE OF LABOR SPECIALIZATION

Specialization of labor

Specialization of labor is the two-edged sword of job design. On one hand, specialization has made possible high-speed, low-cost production, and from a materialistic standpoint, it has greatly enhanced our standard of living. On the other hand, extreme specialization (as we see in mass-production industries) often has serious adverse effects on workers, which in turn are passed on to management. In essence, the problem is to determine how much specialization is enough. At what point do the disadvantages outweigh the advantages? (See Exhibit TN4.2.)

EXHIBIT TN4.2

Advantages and Disadvantages of Specialization of Labor

Advantages of Specialization

To Management	To Labor
1. Rapid training of the workforce	**1.** Little or no education required to obtain work
2. Ease in recruiting new workers	**2.** Ease in learning job
3. High output due to simple, repetitive work	
4. Low wages due to ease of substitutability of labor	
5. Close control over work flow and workloads	

Disadvantages of Specialization

To Management	To Labor
1. Difficulty in controlling quality because no one has responsibility for entire product	**1.** Boredom stemming from repetitive nature of work
2. Worker dissatisfaction leading to hidden costs arising from turnover, absenteeism, tardiness, grievances, and intentional disruption of production process	**2.** Little gratification from work itself because of small contribution to each item
3. Reduced likelihood of improving the process because of workers' limited perspective	**3.** Little or no control over the work pace, leading to frustration and fatigue (in assembly-line situations)
4. Limited flexibility to change the production process to produce new or improved products	**4.** Little opportunity to progress to a better job because significant learning is rarely possible on fractionated work

Recent research suggests that the disadvantages dominate the advantages much more commonly than was thought in the past. However, simply stating that for purely humanitarian reasons, specialization should be avoided is risky. The reason, of course, is that people differ in what they want from their work and what they are willing to put into it. Some workers prefer not to make decisions about their work, some like to daydream on the job, and others are simply not capable of performing more complex work. To improve the quality of jobs, leading organizations try different approaches to job design. Two popular contemporary approaches are job enrichment and sociotechnical systems.

JOB ENRICHMENT

Job enlargement generally entails adjusting a specialized job to make it more interesting to the job holder. A job is said to be enlarged *horizontally* if the worker performs a greater number or variety of tasks, and it is said to be enlarged *vertically* if the worker is involved in planning, organizing, and inspecting his or her own work. Horizontal job enlargement is intended to counteract oversimplification and to permit the worker to perform a "whole unit of work." Vertical enlargement (traditionally termed *job enrichment*) attempts to broaden workers' influence in the transformation process by giving them certain managerial powers over their own activities. Today, common practice is to apply both horizontal and vertical enlargement to a given job and refer to the total approach as **job enrichment.**

Job enrichment

The organizational benefits of job enrichment occur in both quality and productivity. Quality in particular improves dramatically because when individuals are responsible for their work output, they take ownership of it and simply do a better job. Also, because they have a broader understanding of the work process, they are more likely to catch errors and make corrections than if the job is narrowly focused. Productivity improvements also occur from job enrichment, but they are not as predictable or as large as the improvements in quality. The reason is that enriched work invaribly contains a mix of tasks that (for manual labor) causes interruptions in rhythm and different motions when switching from one task to the next. Such is not the case for specialized jobs.[1]

SOCIOTECHNICAL SYSTEMS

Sociotechnical systems

Consistent with the job enrichment philosophy but focusing more on the interaction between technology and the work group is the **sociotechnical systems** approach. This approach attempts to develop jobs that adjust the needs of the production process technology to the needs of the worker and work group. The term was developed from studies of weaving mills in India and of coal mines in England in the early 1950s. These studies revealed that work groups could effectively handle many production problems better than management if they were permitted to make their own decisions on scheduling, work allocation among members, bonus sharing, and so forth. This was particularly true when variations in the production process required quick reactions by the group or when one shift's work overlapped with other shifts' work.

Since those pioneering studies, the sociotechnical approach has been applied in many countries—often under the heading of "autonomous work groups," "Japanese-style work groups," or employee involvement (EI) teams. Most major American manufacturing companies use work teams as the basic building block in so-called high employee involvement plants. They are now becoming common in service organizations as well. The benefits of teams are similar to those of individual job enrichment: They provide higher quality and greater productivity (they often set higher production goals than general management), do their own support work and equipment maintenance, and have increased chances to make meaningful improvements.[2]

One major conclusion from these applications is that the individual or work group requires a logically integrated pattern of work activities that incorporates the following job design principles:

1 **Task variety.** An attempt must be made to provide an optimal variety of tasks within each job. Too much variety can be inefficient for training and frustrating for

the employee. Too little can lead to boredom and fatigue. The optimal level is one that allows the employee to rest from a high level of attention or effort while working on another task or, conversely, to stretch after periods of routine activity.

2 **Skill variety.** Research suggests that employees derive satisfaction from using a number of skill levels.

3 **Feedback.** There should be some means for informing employees quickly when they have achieved their targets. Fast feedback aids the learning process. Ideally, employees should have some responsibility for setting their own standards of quantity and quality.

4 **Task identity.** Sets of tasks should be separated from other sets of tasks by some clear boundary. Whenever possible, a group or individual employee should have responsibility for a set of tasks that is clearly defined, visible, and meaningful. In this way, work is seen as important by the group or individual undertaking it, and others understand and respect its significance.

5 **Task autonomy.** Employees should be able to exercise some control over their work. Areas of discretion and decision making should be available to them.[3]

PHYSICAL CONSIDERATIONS IN JOB DESIGN

Beyond the behavioral components of job design, another aspect warrants consideration: the physical side. Indeed, while motivation and work group structure strongly influence job performance, they may be of secondary importance if the job is too demanding from a physical (or "human factors") standpoint. One approach to incorporating the physical costs of moderate to heavy work in job design is **work physiology.** Pioneered by Eastman Kodak in the 1960s, work physiology sets work–rest cycles according to the energy expended in various parts of the job. For example, if a job entails caloric expenditure above five calories per minute (the rough baseline for sustainable work), the required rest period must equal or exceed the time spent working. Obviously, the harder the work, the more frequent and longer the rest periods. (Exhibit TN4.3 shows caloric requirements for various activities.)

Work physiology

Ergonomics is the term used to describe the study of the physical arrangement of the work space together with the tools used to perform a task. In applying ergonomics, we

Ergonomics

EXHIBIT TN4.3

Calorie Requirements for Various Activities

Type of Activity	Typical Energy Cost in Calories per Minute*	Required Minutes of Rest for Each Minute of Work
Sitting at rest	1.7	—
Writing	2.0	—
Typing on a computer	2.0	—
Medium assembly work	2.9	—
Shoe repair	3.0	—
Machining	3.3	—
Ironing	4.4	—
Heavy assembly work	5.1	—
Chopping wood	7.5	1
Digging	8.9	2
Tending furnace	12.0	3
Walking upstairs	12.0	3

*Five calories per minute is generally considered the maximum sustainable level throughout the workday.

ON THIS MICROWAVE OVEN ASSEMBLY, THE WORK PROCESS HAS BEEN DESIGNED TO FIT THE WORKER RATHER THAN FORCING THE EMPLOYEES TO CONFORM TO THE WORK.

strive to fit the work to the body rather than forcing the body to conform to the work. As logical as this may sound, it is actually a recent point of view.

WORK METHODS

In contemporary industry, responsibility for developing work methods in large firms is typically assigned either to a staff department designated *methods analysis* or to an industrial engineering department. In small firms, this activity is often performed by consulting firms that specialize in work methods design.

The principal approach to the study of work methods is the construction of charts, such as operations charts, worker–machine charts, simo (simultaneous motion) charts, and activity charts, in conjunction with time study or standard time data. The choice of which charting method to use depends on the task's activity level—that is, whether the focus is on (1) a production process, (2) the worker at a fixed workplace, (3) a worker interacting with equipment, or (4) a worker interacting with other workers (see Exhibit TN4.4). (These charting techniques were introduced in Chapter 4, where they were used to aid in process analysis. Chapter 6 introduces the service blueprint that accounts for customer interactions.)

A PRODUCTION PROCESS

The objective in studying a production process is to identify delays, transport distances, processes, and processing time requirements to simplify the entire operation. The underlying philosophy is to eliminate any step in the process that does not add value to the product. The approach is to flowchart the process and then ask the following questions:

What is done? Must it be done? What would happen if it were not done?

Where is the task done? Must it be done at that location or could it be done somewhere else?

When is the task done? Is it critical that it be done then or is there flexibility in time and sequence? Could it be combined with some other step in the process?

How is the task done? Why is it done this way? Is there another way?

Who does the task? Can someone else do it? Should the worker be of a higher or lower skill level?

EXHIBIT TN4.4

Work Methods Design Aids

ACTIVITY	OBJECTIVE OF STUDY	STUDY TECHNIQUES
Production process	Eliminate or combine steps; shorten transport distance; identify delays	Flow diagram, service blueprint, process chart
Worker at fixed workplace	Simplify method; minimize motions	Operations charts, simo charts; apply principles of motion economy
Worker's interaction with equipment	Minimize idle time; find number or combination of machines to balance cost of worker and machine idle time	Activity chart, worker–machine charts
Worker's interaction with other workers	Maximize productivity; minimize interference	Activity charts, gang process charts

These thought-provoking questions usually help eliminate much unnecessary work and simplify the remaining work by combining processing steps and changing the order of performance.

The process chart is valuable in studying an overall system, though care must be taken to follow the same item throughout the process. The subject may be a product being manufactured, a service being created, or a person performing a sequence of activities. Exhibit TN4.5 shows a process chart (and flow diagram) for a clerical operation. Exhibit TN4.6 shows common notation in process charting. Can you suggest any ways to improve this process? (See Problem 2.)

WORKER AT A FIXED WORKPLACE

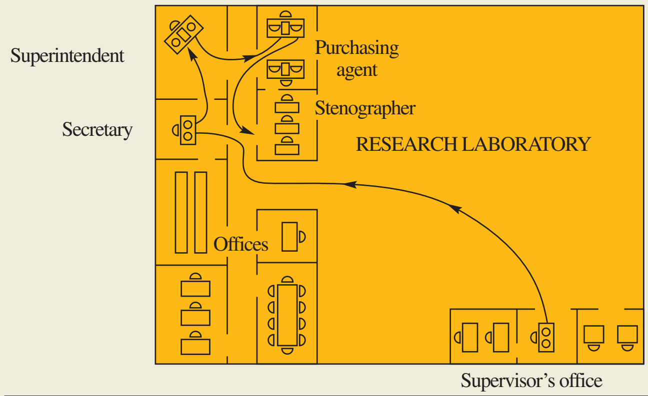
Many jobs require the worker to remain at a specified workstation. When the nature of the work is primarily manual (such as sorting, inspecting, making entries, or assembly operations), the focus of work design is on simplifying the work method and making the required operator motions as few and as easy as possible.

There are two basic ways to determine the best method when a methods analyst studies a single worker performing an essentially manual task. The first is to search among the workers and find the one who performs the job best. That person's method is then accepted as the standard, and others are trained to perform it in the same way. This was basically F. W. Taylor's approach, though after determining the best method, he searched for "first-class men" to perform according to the method. (A first-class worker possessed the natural ability to do much more productive work in a particular task than the average. Workers who were not first class were transferred to other jobs.) The second way is to observe the performance of a number of workers, analyze in detail each step of their work, and pick out the superior features of each worker's performance. This results in a composite method that combines the best elements of the group studied. Frank Gilbreth, the father of motion study, used this procedure to determine the "one best way" to perform a work task.

Taylor observed actual performance to find the best method; Frank Gilbreth and his wife Lillian studied movie film as shown on the right. Through micromotion analysis—observing the filmed work performance frame by frame—the Gilbreths studied work very closely and defined its basic elements, which were termed *therbligs* ("Gilbreth" spelled backward, with the *t* and *h* transposed). As part of his work, Gilbreth constructed wire representations of the path of motion. Their study led to the rules or principles of motion economy, such as "The hands should begin and complete the motions at the same time" and "Work should be arranged to permit natural rhythm."

EXHIBIT TN4.5

Flow Diagram and Process Chart of an Office Procedure—Present Method



Present Method ☒		PROCESS CHART	
Proposed Method ☐			
SUBJECT CHARTED	Requisition for small tools	DATE	
Chart begins at supervisor's desk and ends at		CHART BY	J.C.H.
typist's desk in purchasing department		CHART NO.	R136
DEPARTMENT	Research laboratory	SHEET NO.	1 OF 1

DIST. IN FEET	TIME IN MINS.	CHART SYMBOLS	PROCESS DESCRIPTION
	30	● ⇨ □ D ▽	Requisitions written by supervisor (one copy)
	180	○ ⇨ □ **D** ▽	On supervisor's desk (awaiting messenger)
65	1	○ ➡ □ D ▽	By messenger to superintendent's secretary
	120	○ ⇨ □ **D** ▽	On secretary's desk (awaiting typing)
	30	● ⇨ □ D ▽	Requisition typed (original requisition copied)
15	.5	○ ➡ □ D ▽	By secretary to superintendent
	480	○ ⇨ □ **D** ▽	On superintendent's desk (awaiting messenger)
	15	○ ⇨ ■ D ▽	Examined and approved
	480	○ ⇨ □ **D** ▽	On superintendent's desk (awaiting approval)
20	.5	○ ➡ □ D ▽	To purchasing department
	240	○ ⇨ □ **D** ▽	On purchasing agent's desk (awaiting approval)
	30	○ ⇨ ■ D ▽	Examined and approved
	240	○ ⇨ □ **D** ▽	On purchasing agent's desk (awaiting messenger)
5	.25	○ ➡ □ D ▽	To stenographer's desk
	120	○ ⇨ □ **D** ▽	On stenographer's desk (awaiting typing of purchase order)
	30	● ⇨ □ D ▽	Purchase order typed
	240	○ ⇨ □ **D** ▽	On stenographer's desk (awaiting transfer to main office)
		○ ⇨ □ D ▽	
105	2237.25	3 4 2 8	Total

NOTE: Requisition is written by a supervisor, typed by a secretary, approved by a superintendent, and approved by a purchasing agent. Then a purchase order is prepared by a stenographer.

EXHIBIT TN4.6

Notation for the Process Chart in Exhibit TN4.5

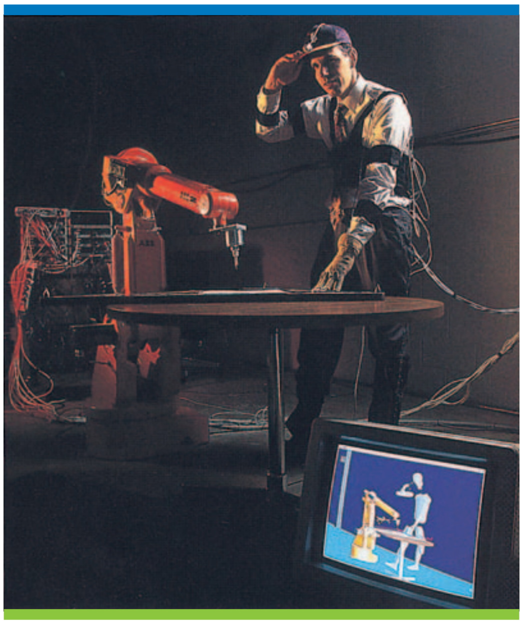
- ● Operation. Something is actually being done. This may be work on a product, some support activity, or anything that is directly productive in nature.
- ➡ Transportation. The subject of the study (product, service, or person) moves from one location to another.
- ■ Inspection. The subject is observed for quality and correctness.
- **D** Delay. The subject of the study must wait before starting the next step in the process.
- ▼ Storage. The subject is stored, such as finished products in inventory or completed papers in a file. Frequently, a distinction is made between temporary storage and permanent storage by inserting a T or P in the triangle.

Once the motions for performing the task have been identified, an *operations chart* may be made, listing the operations and their sequence of performance. For greater detail, a *simo* (simultaneous motion) *chart* may be constructed, listing not only the operations but also the times for both left and right hands. This chart may be assembled from the data collected with a stopwatch, from analysis of a film of the operation, or from predetermined motion–time data (discussed later in the chapter). Many aspects of poor design are immediately obvious: a hand being used as a holding device (rather than a jig or fixture), an idle hand, or an exceptionally long time for positioning.

WORKER INTERACTING WITH EQUIPMENT

When a person and equipment operate together to perform a productive process, interest focuses on the efficient use of the person's time and equipment time. When the operator's working time is less than the equipment run time, a worker–machine chart is a useful device in analysis. If the operator can operate several pieces of equipment, the problem is to find the most economical combination of operator and equipment, when the combined cost of the idle time of a particular combination of equipment and the idle time for the worker is at a minimum.

Worker–machine charts are always drawn to scale, the scale being time as measured by length. Exhibit TN4.7 shows a worker–machine chart in a service setting. The question here is, whose utilization use is most important?



SOFTWARE FROM DENEB ROBOTICS IS DESIGNED TO HELP COMPANIES PLAN TO MEET PRODUCTION GOALS. WEARING A HARNESS WITH 11 SENSORS, THE WORKER DEMONSTRATES SOFTWARE THAT HELPS ENGINEERS MAXIMIZE EFFICIENCY ON A PRODUCTION LINE BY COORDINATING THE MOVEMENTS OF HUMANS AND ROBOTS WORKING SIDE BY SIDE (SEE THE MONITOR).

EXHIBIT TN4.7

Worker–Machine Chart for a Gourmet Coffee Store

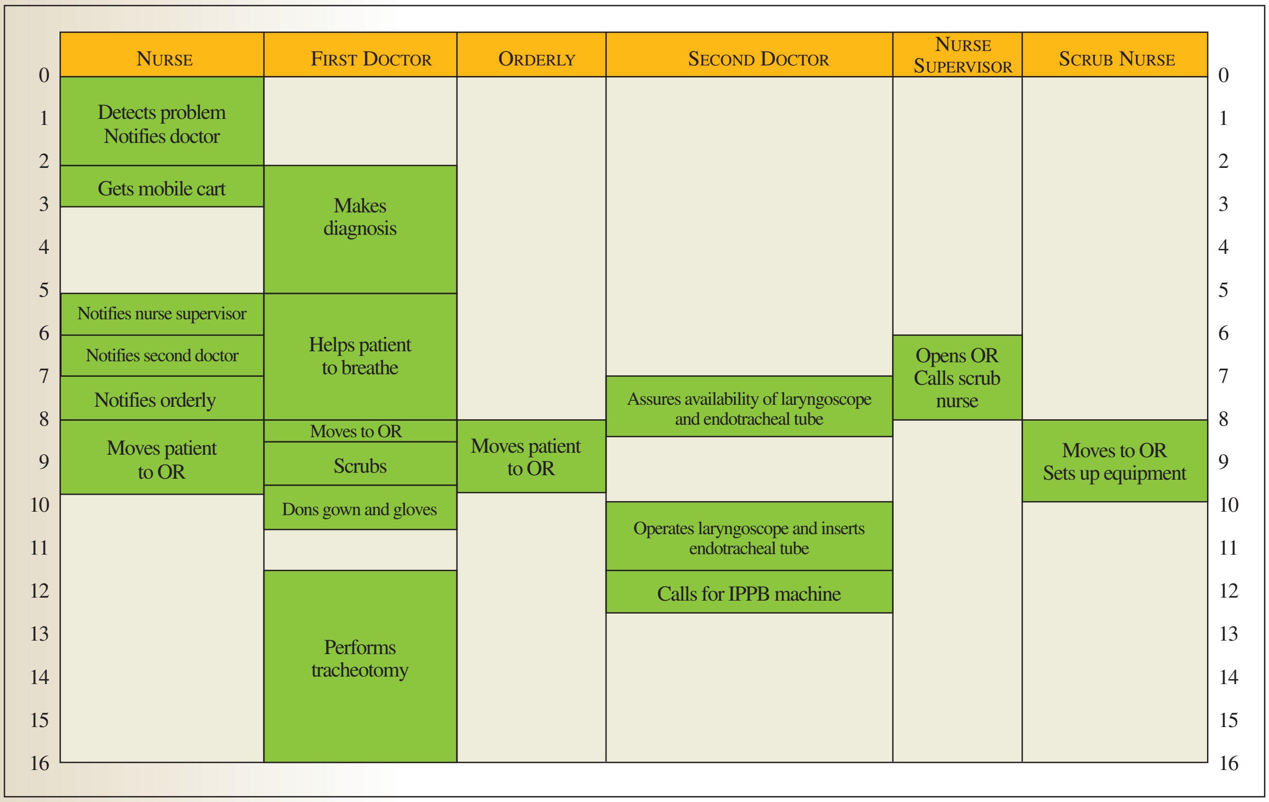
Time in Seconds	Person				Machine	
	Customer	Time in sec.	Clerk	Time in sec.	Coffee Grinder	Time in sec.
0	1. Ask grocer for 1 pound of coffee (brand and grind)	5	Listen to order	5	Idle	5
10–20	2. Wait	15	Get coffee and put in machine, set grind, and start grinder	15	Idle	15
20–40	3. Wait	21	Idle while machine grinds	21	Grind coffee	21
40–50	4. Wait	12	Stop grinder, place coffee in package, and close it	12	Idle	12
50–70	5. Receive coffee from grocer, pay grocer, and receive change	17	Give coffee to customer, wait for customer to pay for coffee, receive money, and make change	17	Idle	17

Summary

	Customer	Clerk	Coffee Grinder
Idle Time	48 sec.	21 sec.	49 sec.
Working Time	22	49	21
Total Cycle Time	70	70	70
Utilization Percentage	Customer utilization = $\frac{22}{70} = 31\%$	Clerk utilization = $\frac{49}{70} = 70\%$	Machine utilization = $\frac{21}{70} = 30\%$

The customer, the clerk, and the coffee grinder (machine) are involved in this operation. It required 1 minute 10 seconds for the customer to purchase a pound of coffee in this store. During this time the customer spent 22 seconds, or 31 percent of the time, giving the clerk his order, receiving the ground coffee, and paying the clerk. He was idle the remaining 69 percent of the time. The clerk worked 49 seconds, or 70 percent of the time, and was idle 21 seconds, or 30 percent of the time. The coffee grinder was in operation 21 seconds, or 30 percent of the time, and was idle 70 percent of the time.

EXHIBIT TN4.8 Activity Chart of Emergency Tracheotomy



SOURCE: DATA TAKEN FROM H. E. SMALLEY AND J. FREEMAN, *HOSPITAL INDUSTRIAL ENGINEERING* (NEW YORK: REINHOLD, 1966), P. 409.

WORKERS INTERACTING WITH OTHER WORKERS

The degree of interaction among teams may be as simple as one operator handing a part to another, or as complex as a cardiovascular surgical team of doctors, nurses, anesthesiologist, operator of an artificial heart machine, X-ray technician, standby blood donors, and pathologist (and perhaps a minister to pray a little).

An activity or a gang process chart is useful in plotting each individual's activities on a time scale similar to that of the worker–machine chart. A *gang process chart* is usually employed to trace the interaction of a number of workers with machines in a specified operating cycle to find the best combination of workers and machines. An *activity chart* is less restrictive and may be used to follow the interaction of any group of operators, with or without equipment being involved. Such charts are often used to study and define each operation in an ongoing repetitive process, and they are extremely valuable in developing a standardized procedure for a specific task. Exhibit TN4.8, for example, shows an activity chart for a hospital's emergency routine in performing a tracheotomy (opening a patient's throat surgically to allow the patient to breathe), where detailed activity analysis is critical and any delay could be fatal.

WORK MEASUREMENT AND STANDARDS

Work measurement

The fundamental purpose of **work measurement** is to set time standards for a job. Such standards are necessary for four reasons:

1 **To schedule work and allocate capacity.** All scheduling approaches require some estimate of how much time it takes to do the work being scheduled.

2 **To provide an objective basis for motivating the workforce and measuring workers' performance.** Measured standards are particularly critical where output-based incentive plans are employed.
3 **To bid for new contracts and to evaluate performance on existing ones.** Questions such as "Can we do it?" and "How are we doing?" presume the existence of standards.
4 **To provide benchmarks for improvement.** In addition to internal evaluation, benchmarking teams regularly compare work standards in their company with those of similar jobs in other organizations.

Work measurement and its resulting work standards have been controversial since Taylor's time. Much of this criticism has come from unions, which argue that management often sets standards that cannot be regularly achieved. (To counter this, in some contracts, the industrial engineer who sets the standard must demonstrate that he or she can do the job over a representative period of time at the rate that was set.) There is also the argument that workers who find a better way of doing the job get penalized by having a revised rate set. (This is commonly called *rate cutting*.)

With the widespread adoption of W. Edwards Deming's ideas, the subject has received renewed criticism. Deming argued that work standards and quotas inhibit process improvement and tend to focus the worker's efforts on speed rather than quality.

Despite these criticisms, work measurement and standards have proved effective. Much depends on sociotechnical aspects of the work. Where the job requires work groups to function as teams and create improvements, worker-set standards often make sense. On the other hand, where the job really boils down to doing the work quickly, with little need for creativity (such as delivering packages for UPS as the box on page 136 relates), tightly engineered, professionally set standards are appropriate.

WORK MEASUREMENT TECHNIQUES

There are two common techniques for measuring work and setting standards: time study and work sampling. The choice of techniques depends on the level of detail desired and the nature of the work itself. Highly detailed, repetitive work usually calls for time study analysis. When work is infrequent or entails a long cycle time, work sampling is the tool of choice.

A **time study** is generally made with a stopwatch, either on the spot or by analyzing a videotape for the job. The job or task to be studied is separated into measurable parts or elements, and each element is timed individually. Time study

Some general rules for breaking down the elements are

1 Define each work element to be short in duration but long enough so that it can be timed with a stopwatch and the time can be written down.
2 If the operator works with equipment that runs separately (meaning the operator performs a task and the equipment runs independently), separate the actions of the operator and of the equipment into different elements.
3 Define any delays by the operator or equipment into separate elements.

After a number of repetitions, the collected times are averaged. (The standard deviation may be computed to give a measure of variance in the performance times.) The averaged times for each element are added, yielding the performance time for the operator. However, to make this operator's time usable for all workers, a measure of speed or *performance rating* must be included to "normalize" the job. The application of a rating factor gives what is called *normal time*. For example, if an operator performs a task in two minutes and the time-study analyst estimates her to be performing about 20 percent faster than normal, the operator's performance rating would be 1.2 or 120 percent of normal. The normal time would be computed as 2 minutes $\times$ 1.2, or 2.4 minutes. In equation form,

Normal time = observed performance time per unit $\times$ Performance rating Normal time

WORK MEASUREMENT AT UNITED PARCEL SERVICE

LOADING EFFICIENCY IS STUDIED EXTENSIVELY BY UPS, RESULTING IN UPS TRUCKS THAT CARRY AS MUCH AS 30 PERCENT MORE PACKAGES THAN AN AVERAGE TRUCK.

Grabbing a package under his arm, Joseph Polise, a driver for United Parcel Service (UPS), bounds from his brown delivery truck and toward an office building here. A few paces behind him, Marjorie Cusack, a UPS industrial engineer, clutches a digital timer.

Her eyes fixed on Polise, she counts his steps and times his contact with customers. Scribbling on a clipboard, Cusack records every second taken up by stoplights, traffic, detours, doorbells, walkways, stairways, and coffee breaks.

Eighty thousand UPS drivers travel 1.2 billion miles per year and deliver more than 13 million packages a day. On average, UPS drivers move in and out of the truck 200 times a day. An unnecessary step or indirect travel path reduces the effectiveness of the driver and impacts service to the customer. One minute saved each day saves the company $5 million annually. For this reason, UPS spends millions each year to train its drivers in proper, efficient, and safe work methods.

Approximately 1,118 industrial engineers at UPS ensure efficient and reliable customer service by conducting time studies on drivers' routes to provide job method instruction. They have measured even the finest details of the drivers' job, including determining on which finger drivers should consistently carry their key rings to avoid losing them.

In addition to developing specific job methods, UPS provides drivers with custom-built package vehicles with features including

- Domed seats that allow the driver to slide on and off easily at each delivery stop.
- A drop floor well located behind the rear wheel housing, making the rear of the vehicle only a short step from the ground for easy entry.
- Bulkhead doors that allow easy access to the package compartment and save the driver steps in selecting parcels for delivery.

SOURCE: ABSTRACTED FROM D. MACHALABA, "UP TO SPEED: UNITED PARCEL SERVICE GETS DELIVERIES DONE BY DRIVING ITS WORKERS," *THE WALL STREET JOURNAL*, APRIL 22, 1986, P. 1. INFORMATION PROVIDED BY UPS, 1999.

In this example, denoting normal time by *NT*,

$$NT = 2\,(1.2) = 2.4 \text{ minutes}$$

When an operator is observed for a period of time, the number of units produced during this time, along with the performance rating, gives

$$NT = \frac{\text{Time worked}}{\text{Number of units produced}} \times \text{Performance rating}$$

Standard time

Standard time is derived by adding to normal time allowances for personal needs (such as washroom and coffee breaks), unavoidable work delays (such as equipment breakdown or lack of materials), and worker fatigue (physical or mental). Two such equations are

$$\text{Standard time} = \text{Normal time} + (\text{Allowances} \times \text{Normal time})$$

or

[TN4.1] $$ST = NT\,(1 + \text{Allowances})$$

and

$$ST = \frac{NT}{1 - \text{Allowances}} \qquad \text{[TN4.2]}$$

Equation (TN4.1) is most often used in practice. If one presumes that allowances should be applied to the total work period, then equation (TN4.2) is the correct one. To illustrate, suppose that the normal time to perform a task is one minute and that allowances for personal needs, delays, and fatigue total 15 percent; then by equation (TN4.1)

$$ST = 1(1 + 0.15) = 1.15 \text{ minutes}$$

In an eight-hour day, a worker would produce $8 \times 60/1.15$, or 417 units. This implies 417 minutes working and $480 - 417$ (or 63) minutes for allowances.

With equation (TN4.2),

$$ST = \frac{1}{1 - 0.15} = 1.18 \text{ minutes}$$

In the same eight-hour day, $8 \times 60/1.18$ (or 408) units are produced with 408 working minutes and 72 minutes for allowances. Depending on which equation is used, there is a difference of nine minutes in the daily allowance time.

EXAMPLE TN4.1: Time Study for a Four-Element Job

Exhibit TN4.9 shows a time study of 10 cycles of a four-element job. For each element, there is a space for the watch readings that are recorded in 100ths of a minute. Space is also provided for summarizing the data and applying a performance rating.

SOLUTION

The value of $\overline{T}$ is obtained by averaging the observed data. PR denotes the performance rating and is multiplied with $\overline{T}$ to obtain the normal time (NT) for each element. The normal time for the job is the sum of the element normal times. The standard time, calculated according to equation (TN4.1), is given at the bottom of Exhibit TN4.9. ●

EXHIBIT TN4.9

Time-Study Observation Sheet

Time Study Observation Sheet

Identification of Operation *ASSEMBLE 24″ × 36″ CHART BLANKS* — Date *10/9*

Began Timing: *9:26* Ended Timing: *9:32* — Operator 109 — Approval — Observer

	Element Description and Breakpoint	1 (0.00)	2	3	4	5	6	7	8	9	10	ΣT	$\overline{T}$	PR	NT
1	*Fold over end (grasp stapler)*	.07	.07	.05	.07	.09	.06	.05	.08	.08	.06	.68	.07	.90	.06
		.07	.61	.14	.67	.24	.78	.33	.88	.47	.09				
2	*Staple five times (drop stapler)*	.16	.14	.14	.15	.16	.16	.14	.17	.14	.15	1.51	.15	1.05	.16
		.23	.75	.28	.82	.40	.94	.47	.05	.61	.24				
3	*Bend and insert wire (drop pliers)*	.22	.25	.22	.25	.23	.23	.21	.26	.25	.24	2.36	.24	1.00	.24
		.45	.00	.50	.07	.63	.17	.68	.31	.86	.48				
4	*Dispose of finished chart (touch next sheet)*	.09	.09	.10	.08	.09	.11	.12	.08	.17	.08	1.01	.10	.90	.09
		.54	.09	.60	.15	.72	.28	.80	.39	.03	.56			*0.55 normal minute for cycle*	
5															
6															
10															

Normal cycle time *0.55* + Allowance *(0.55 × 0.143) or 0.08* = Std. time *0.63 min./pc.*

How many observations are enough? Time study is really a sampling process; that is, we take relatively few observations as being representative of many subsequent cycles to be performed by the worker. Based on a great deal of analysis and experience, Benjamin Niebel's table shown in Exhibit TN4.10 indicates that "enough" is a function of cycle length and number of repetitions of the job over a one-year planning period.

Work sampling

A second common technique for measuring a job is called work sampling. As the name suggests, **work sampling** involves observing a portion or sample of the work activity. Then, based on the findings in this sample, statements can be made about the activity. For example, if we were to observe a fire department rescue squad at 100 random times during the day and found it was involved in a rescue mission for 30 of the 100 times (en route, on site, or returning from a call), we would estimate that the rescue squad spends 30 percent of its time directly on rescue mission calls. (The time it takes to make an observation depends on what is being observed. Many times, only a glance is needed to determine the activity, and the majority of studies require only several seconds' observation.)

Service

Observing an activity even 100 times may not, however, provide the accuracy desired in the estimate. To refine this estimate, three main issues must be decided. (These points are discussed later in this section, along with an example.)

1 What level of statistical confidence is desired in the results?
2 How many observations are necessary?
3 Precisely when should the observations be made?

The three primary applications for work sampling are

1 Ratio delay to determine the activity-time percentage for personnel or equipment. For example, management may be interested in the amount of time a machine is running or idle.

EXHIBIT TN4.10

Guide to Number of Cycles to Be Observed in a Time Study

When Time per Cycle Is More Than	Minimum Number of Cycles of Study (Activity)		
	Over 10,000 per Year	1,000–10,000	Under 1,000
8 hours	2	1	1
3	3	2	1
2	4	2	1
1	5	3	2
48 minutes	6	3	2
30	8	4	3
20	10	5	4
12	12	6	5
8	15	8	6
5	20	10	8
3	25	12	10
2	30	15	12
1	40	20	15
.7	50	25	20
.5	60	30	25
.3	80	40	30
.2	100	50	40
.1	120	60	50
Under .1	140	80	60

SOURCE: B. W. NIEBEL, *MOTION AND TIME STUDY*, 9TH ED. (BURR RIDGE, IL: RICHARD D. IRWIN, 1993), P. 390.

2 Performance measurement to develop a performance index for workers. When the amount of work time is related to the quantity of output, a measure of performance is developed. This is useful for periodic performance evaluation.

3 Time standards to obtain the standard time for a task. When work sampling is used for this purpose, however, the observer must be experienced because he or she must attach a performance rating to the observations.

The number of observations required in a work-sampling study can be fairly large, ranging from several hundred to several thousand, depending on the activity and desired degree of accuracy. Although the number can be computed from formulas, the easiest way is to refer to a table such as Exhibit TN4.11, which gives the number of observations needed for a 95 percent confidence level in terms of absolute error. *Absolute error* is the actual range of the observations. For example, if a clerk is idle 10 percent of the time and the designer of the study is satisfied with a 2.5 percent range (meaning that the true percentage lies between 7.5 and 12.5 percent), the number of observations required for the work sampling is 576. A 2 percent error (or an interval of 8 to 12 percent) would require 900 observations.

Five steps are involved in making a work-sampling study:

1 Identify the specific activity or activities that are the main purpose for the study. For example, determine the percentage of time that equipment is working, idle, or under repair.

2 Estimate the proportion of time of the activity of interest to the total time (e.g., that the equipment is working 80 percent of the time). These estimates can be made from the analyst's knowledge, past data, reliable guesses from others, or a pilot work-sampling study.

3 State the desired accuracy in the study results.

4 Determine the specific times when each observation is to be made.

5 At two or three intervals during the study period, recompute the required sample size by using the data collected thus far. Adjust the number of observations if appropriate.

The number of observations to be taken in a work-sampling study is usually divided equally over the study period. Thus, if 500 observations are to be made over a 10-day period, observations are usually scheduled at 500/10, or 50 per day. Each day's observations are then assigned a specific time by using a random number table.

EXAMPLE TN4.2: Work Sampling Applied to Nursing

Service

There has been a long-standing argument that a large amount of nurses' hospital time is spent on nonnursing activities. This, the argument goes, creates an apparent shortage of well-trained nursing personnel, wastes talent, hinders efficiency, and increases hospital costs because nurses' wages are the highest single cost in the operation of a hospital. Further, pressure is growing for hospitals and hospital administrators to contain costs. With that in mind, let us use work sampling to test the hypothesis that a large portion of nurses' time is spent on nonnursing duties.

SOLUTION

Assume at the outset that we have made a list of all the activities that are part of nursing and will make our observations in only two categories: nursing and nonnursing activities. Actually, there is much debate on what constitutes nursing activity. For instance, is talking to a patient a nursing duty? (An expanded study could list all nursing activities to determine the portion of time spent in each.) Therefore, when we observe during the study and find the nurse performing one of the duties on the nursing list, we simply place a tally mark in the nursing column. If we observe anything besides nursing activities, we place a tally mark in the nonnursing column.

We can now plan the study. Assume that we (or the nursing supervisor) estimate that nurses spend 60 percent of their time in nursing activities. Assume that we would like to be 95 percent confident that findings of our study are within the absolute error range of ± 3 percent; that is, if our study shows nurses spend 60 percent of their time on nursing duties, we want to be 95 percent confident that the

EXHIBIT TN4.11

Number of Observations Required for a Given Absolute Error at Various Values of *p*, with 95 Percent Confidence Level

PERCENTAGE OF TOTAL TIME OCCUPIED BY ACTIVITY OR DELAY, *P*	ABSOLUTE ERROR					
	±1.0%	±1.5%	±2.0%	±2.5%	±3.0%	±3.5%
1 or 99	396	176	99	63	44	32
2 or 98	784	348	196	125	87	64
3 or 97	1,164	517	291	186	129	95
4 or 96	1,536	683	384	246	171	125
5 or 95	1,900	844	475	304	211	155
6 or 94	2,256	1,003	564	361	251	184
7 or 93	2,604	1,157	651	417	289	213
8 or 92	2,944	1,308	736	471	327	240
9 or 91	3,276	1,456	819	524	364	267
10 or 90	3,600	1,600	900	576	400	294
11 or 89	3,916	1,740	979	627	435	320
12 or 88	4,224	1,877	1,056	676	469	344
13 or 87	4,524	2,011	1,131	724	503	369
14 or 86	4,816	2,140	1,204	771	535	393
15 or 85	5,100	2,267	1,275	816	567	416
16 or 84	5,376	2,389	1,344	860	597	439
17 or 83	5,644	2,508	1,411	903	627	461
18 or 82	5,904	2,624	1,476	945	656	482
19 or 81	6,156	2,736	1,539	985	684	502
20 or 80	6,400	2,844	1,600	1,024	711	522
21 or 79	6,636	2,949	1,659	1,062	737	542
22 or 78	6,864	3,050	1,716	1,098	763	560
23 or 77	7,084	3,148	1,771	1,133	787	578
24 or 76	7,296	3,243	1,824	1,167	811	596
25 or 75	7,500	3,333	1,875	1,200	833	612
26 or 74	7,696	3,420	1,924	1,231	855	628
27 or 73	7,884	3,504	1,971	1,261	876	644
28 or 72	8,064	3,584	2,016	1,290	896	658
29 or 71	8,236	3,660	2,059	1,318	915	672
30 or 70	8,400	3,733	2,100	1,344	933	686
31 or 69	8,556	3,803	2,139	1,369	951	698
32 or 68	8,704	3,868	2,176	1,393	967	710
33 or 67	8,844	3,931	2,211	1,415	983	722
34 or 66	8,976	3,989	2,244	1,436	997	733
35 or 65	9,100	4,044	2,275	1,456	1,011	743
36 or 64	9,216	4,096	2,304	1,475	1,024	753
37 or 63	9,324	4,144	2,331	1,492	1,036	761
38 or 62	9,424	4,188	2,356	1,508	1,047	769
39 or 61	9,516	4,229	2,379	1,523	1,057	777
40 or 60	9,600	4,266	2,400	1,536	1,067	784
41 or 59	9,676	4,300	2,419	1,548	1,075	790
42 or 58	9,744	4,330	2,436	1,559	1,083	795
43 or 57	9,804	4,357	2,451	1,569	1,089	800
44 or 56	9,856	4,380	2,464	1,577	1,095	804
45 or 55	9,900	4,400	2,475	1,584	1,099	808
46 or 54	9,936	4,416	2,484	1,590	1,104	811
47 or 53	9,964	4,428	2,491	1,594	1,107	813
48 or 52	9,984	4,437	2,496	1,597	1,109	815
49 or 51	9,996	4,442	2,499	1,599	1,110	816
50	10,000	4,444	2,500	1,600	1,111	816

Note: Number of observations is obtained from the formula $E = Z\sqrt{\frac{p(1-p)}{N}}$ and the required sample (N) is $N = \frac{Z^2 p(1-p)}{E^2}$
where E = Absolute error
p = Percentage occurrence of activity or delay being measured
N = Number of random observations (sample size)
Z = Number of standard deviations to give desired confidence level (e.g., for 90 percent confidence, $Z = 1.65$; for 95 percent, $Z = 1.96$; for 99 percent, $Z = 2.23$). In this table $Z = 2$.

true percentage lies between 57 and 63 percent. From Exhibit TN4.11, we find that 1,067 observations are required for 60 percent activity time and ±3 percent error. If our study is to take place over 10 days, we start with 107 observations per day.

To determine when each day's observations are to be made, we assign specific numbers to each minute and use a random number table to set up a schedule. If the study extends over an eight-hour shift, we can assign numbers to correspond to each consecutive minute. For this study it is likely the night shift would be run separately because nighttime nursing duties are considerably different from daytime duties. Exhibit TN4.12A shows the assignment of numbers to corresponding minutes. For simplicity, because each number corresponds to one minute, a three-number scheme is used, with the second and third numbers corresponding to the minute of the hour. A number of other schemes would also be appropriate. If a number of studies are planned, a computer program may be used to generate a randomized schedule for the observation times.

If we refer to a random number table and list three-digit numbers, we can assign each number to a time. The random numbers in Exhibit TN4.12B demonstrate the procedure for seven observations.

This procedure is followed to generate 107 observation times, and the times are rearranged chronologically for ease in planning. Rearranging the times determined in Exhibit TN4.12B gives the total observations per day shown in Exhibit TN4.12C (for our sample of seven).

To be perfectly random in this study, we should also "randomize" the nurse we observe each time. (The use of various nurses minimizes the effect of bias.) In the study, our first observation is made at 7:13 A.M. for Nurse X. We walk into the nurse's area and, on seeing the nurse, check either a nursing or a nonnursing activity. Each observation need be only long enough to determine the class of activity—in most cases only a glance is needed. At 8:04 A.M. we observe Nurse Y. We continue in this way to the end of the day and the 107 observations. At the end of the second day (and 214 observations), we decide to check for the adequacy of our sample size.

Let us say we made 150 observations of nurses working and 64 of them not working, which gives 70.1 percent working. From Exhibit TN4.11, this corresponds to 933 observations. Because we have already taken 214 observations, we need take only 719 over the next eight days, or 90 per day.

EXHIBIT TN4.12

Sampling Plan for Nurses' Activities

A. Assignment of Numbers to Corresponding Minutes

B. Determination of Observation Times

C. Observation Schedule

A.

Time	Assigned Numbers
7:00–7:59 A.M.	100–159
8:00–8:59 A.M.	200–259
9:00–9:59 A.M.	300–359
10:00–10:59 A.M.	400–459
11:00–11:59 A.M.	500–559
12:00–12:59 P.M.	600–659
1:00–1:59 P.M.	700–759
2:00–2:59 P.M.	800–859

B.

Random Number	Corresponding Time from the List in TN4.12A
669	Nonexistent
831	2:31 P.M.
555	11:55 A.M.
470	Nonexistent
113	7:13 A.M.
080	Nonexistent
520	11:20 A.M.
204	8:04 A.M.
732	1:32 P.M.
420	10:20 A.M.

C.

Observation	Schedule Time	Nursing Activity(√)	Nonnursing Activity(√)
1	7:13 A.M.		
2	8:04 A.M.		
3	10:20 A.M.		
4	11:20 A.M.		
5	11:55 A.M.		
6	1:32 P.M.		
7	2:31 P.M.		

When the study is half over, another check should be made. For instance, if days 3, 4, and 5 showed 55, 59, and 64 working observations, the cumulative data would give 328 working observations of a total 484, or a 67.8 percent working activity. For a ±3 percent error, Exhibit TN4.11 shows the sample size to be about 967, leaving 483 to be made—at 97 per day—for the following five days. Another computation should be made before the last day to see if another adjustment is required. If after the 10th day several more observations are indicated, these can be made on day 11.

If at the end of the study we find that 66 percent of nurses' time is involved with what has been defined as nursing activity, there should be an analysis to identify the remaining 34 percent. Approximately 12 to 15 percent is justifiable for coffee breaks and personal needs, which leaves 20 to 22 percent of the time that must be justified and compared to what the industry considers ideal levels of nursing activity. To identify the nonnursing activities, a more detailed breakdown could have been originally built into the sampling plan. Otherwise, a follow-up study may be in order. ●

As mentioned earlier, work sampling can be used to set time standards. To do this, the analyst must record the subject's performance rate (or index) along with working observations. Exhibit TN4.13 gives a manufacturing example that demonstrates how work sampling can be used for calculating standard time.

WORK SAMPLING COMPARED TO TIME STUDY

Work sampling offers several advantages:

1. Several work-sampling studies may be conducted simultaneously by one observer.
2. The observer need not be a trained analyst unless the purpose of the study is to determine a time standard.
3. No timing devices are required.
4. Work of a long cycle time may be studied with fewer observer hours.
5. The duration of the study is longer, which minimizes effects of short-period variations.
6. The study may be temporarily delayed at any time with little effect.
7. Because work sampling needs only instantaneous observations (made over a longer period), the operator has less chance to influence the findings by changing his or her work method.

EXHIBIT TN4.13

Deriving a Time Standard Using Work Sampling

INFORMATION	SOURCE OF DATA	DATA FOR ONE DAY
Total time expended by operator (working time and idle time)	Computer payroll system	480 min.
Number of parts produced	Inspection department	420 pieces
Working time in percent	Work sampling	85%
Idle time in percent	Work sampling	15%
Average performance index	Work sampling	110%
Total allowances	Company time-study manual	15%

$$\text{Standard time per piece} = \frac{\left(\begin{array}{c}\text{Total time}\\ \text{in minutes}\end{array}\right) \times \left(\begin{array}{c}\text{Working time}\\ \text{proportion}\end{array}\right) \times \left(\begin{array}{c}\text{Performance}\\ \text{index}\end{array}\right)}{\text{Total number of pieces produced}} \times \frac{1}{1 - \text{Allowances}}$$

$$= \left(\frac{480 \times 0.85 \times 1.10}{420}\right) \times \left(\frac{1}{1 - 0.15}\right) = 1.26 \text{ minutes}$$

When the cycle time is short, time study is more appropriate than work sampling. One drawback of work sampling is that it does not provide as complete a breakdown of elements as time study. Another difficulty with work sampling is that observers, rather than following a random sequence of observations, tend to develop a repetitive route of travel. This may allow the time of the observations to be predictable and thus invalidate the findings. A third factor—a potential drawback—is that the basic assumption in work sampling is that all observations pertain to the same static system. If the system is in the process of change, work sampling may give misleading results.

FINANCIAL INCENTIVE PLANS

The third piece of the job design equation is the paycheck. This section briefly reviews common methods for setting financial incentives.

BASIC COMPENSATION SYSTEMS

The main forms of basic compensation are hourly pay, straight salary, piece rate, and commissions. The first two are based on time spent on the job, with individual performance rewarded by an increase in the base rate. Piece rate plans reward on the basis of direct daily output. (A worker is paid $5 a unit; thus, by producing 10 units per day, the worker earns $50.) Sometimes a guaranteed base is included in a piece-rate plan; a worker would receive this base amount regardless of output, plus a piece-rate bonus. (For example, the worker's hourly base pay is $8, so this coupled with $50 piece-rate earnings gives the worker $114 for an eight-hour day.) Commissions may be thought of as sales-based piece rates and are calculated in the same general way.

The two broad categories of financial incentive plans are individual or small-group incentive plans and organizationwide plans. (See the Breakthrough Box titled "The Fun Factor in Safety Incentive Programs.")

INDIVIDUAL AND SMALL-GROUP INCENTIVE PLANS

Individual and work group plans traditionally have rewarded performance by using output (often defined by piece rates) and quality measures. Quality is accounted for by a quality adjustment factor, say, a percentage of rework.[4] (For example: Incentive pay = Total output × [1 − Percent deduction for rework].) In recent years, skill development has also been rewarded. Sometimes called *pay for knowledge,* this means a worker is compensated for learning new tasks. This is particularly important in job shops using group technology, as well as in banking, where supervisors' jobs require knowledge of new types of financial instruments and selling approaches.

AT&T, for example, instituted incentive programs for its managers—an Individual Incentive Award (IIA) and a Management Team Incentive Award (MTIA). The IIA provides lump-sum bonuses to outstanding performers. These outstanding performers are determined by individual performance ratings accompanied by extensive documentation. The lump-sum bonus can range between 15 and 30 percent of base pay.

MTIAs are granted to members of specific divisions or units. Appropriate division or unit goals are established at the beginning of the year. The goals include department service objectives and interdepartmental goals. A typical MTIA could call for a standard amount equivalent to 1.5 percent of wages plus overtime for the next three years based on performance in the current year.

ORGANIZATIONWIDE PLANS

Profit sharing and gain sharing are the major types of organizationwide plans. Profit sharing simply distributes a percentage of corporate profits across the workforce. In the United States, at least one-third of all organizations have profit sharing. In Japan, most major companies give profit-based bonuses twice a year to all employees. Such bonuses may range from 50 percent of salaries, in good years, to nothing in bad years.

BREAKTHROUGH

THE FUN FACTOR IN SAFETY INCENTIVE PROGRAMS

Here are the basic ingredients for safety incentive programs that apply to other incentive programs as well.

1 **Choose merchandise.** First things first: get the carrot right. Goodyear Tire ran an extensive study on merchandise versus cash incentives; merchandise won twofold. When you ask your people what they want, the answer will be cash. When you ask the experts what really works, it is merchandise.

2 **A flexible award vehicle.** Traditional programs are structured to give a person who goes a year without an accident an award such as a clock radio. In order to attach incentives to the behavior that prevents the accidents, you must have a flexible delivery vehicle that can be awarded the minute the prevention behavior or observation takes place, yet still building up to the resulting merchandise award. Gamecards that contain points toward merchandise have proved an exciting vehicle. They can be handed out weekly or daily, instantly recognizing employees as they achieve safety behavior acts or observations. If the gamecards are designed right, they should have a trading component where employees are encouraged to trade cards with each other. This further boosts program awareness. Having a flexible award vehicle allows for constant frequent reinforcement, which is a key component to a program's success.

3 **An encompassing campaign.** A campaign that communicates and drives the program, tying it all together, is called for. Southwest Airlines is famous for creating fun campaigns for everything it does. People love games (adults, too). The campaign theme should bring everything together: the award vehicle (gamecard, certificate, or the like), merchandise catalog, program posters, newsletters, communication pieces, behavioral observation reports, and so on. People remember things that are constantly in front of them, things that are fun, and things that benefit them.

4 **Simple administration.** Face it, complexity does not work. If your entire program is not easy for everyone to understand, you are headed in the wrong direction. If the program is tough for you to administer, it could fail as well. Keep it simple and achievable.

5 **Well-thought-out, behavior-based program criteria.** You first must identify the behaviors that will affect the majority of incidents. Your program then must be aimed at gathering information/observations and receiving feedback from employees. Employees must be rewarded for these observations as well as for feedback and, of course, for following the accident prevention criteria. Again, keep it simple.

SOURCE: B. PEAVEY, "THE FUN FACTOR," *OCCUPATIONAL HEALTH & SAFETY* 67, NO. 10 (OCTOBER 1998), P. 163.

Gain sharing also involves giving organizationwide bonuses, but it differs from profit sharing in two important respects. First, it typically measures controllable costs or units of output, not profits, in calculating a bonus. Second, gain sharing is always combined with a participative approach to management. The original and best-known gainsharing plan is the Scanlon Plan.

In the late 1930s, the Lapointe Machine and Tool Company was on the verge of bankruptcy, but through the efforts of union president Joseph Scanlon and company management, the Scanlon Plan was devised to save the company by reducing labor costs. In essence, this plan started with the normal labor cost within the firm. Workers as a group were rewarded for any reductions in labor cost below this base cost. The plan's success depended on committees of workers throughout the firm whose purpose was to search out areas for cost saving and to devise ways of improvement. There were many improvements, and the plan did, in fact, save the company.

The basic elements of the Scanlon Plan are

1 **The ratio.** The ratio is the standard that serves as a measure for judging business performance. It can be expressed as

$$\text{Ratio} = \frac{\text{Total labor cost}}{\text{Sales value of production}}$$

2 **The bonus.** The amount of bonus depends on the reduction in costs below the preset ratio.

3 **The production committee.** The production committee is formed to encourage employee suggestions to increase productivity, improve quality, reduce waste, and so forth. The purpose of a production committee is similar to that of a quality circle.

4 **The screening committee.** The screening committee consists of top management and worker representatives who review monthly bonuses, discuss production problems, and consider improvement suggestions.

Gain-sharing plans are now used by more than a thousand firms in the United States and Europe, and are growing in popularity. One survey in the United States indicated that about 13 percent of all firms have them, and that more than 70 percent were started after 1982.[5] Though originally established in small companies such as Lapointe, Lincoln Electric Company, and Herman Miller, gain sharing has been installed by large firms such as TRW, General Electric, Motorola, and Firestone. These companies apply gain sharing to organizational units. Motorola, for example, has virtually all its plant employees covered by gain sharing. These plans are increasing because "they are more than just pay incentive plans; they are a participative approach to management and are often used as a way to install participative management."[6] The typical applications of the plans are discussed, along with merit pay, in Exhibit TN4.14.

PAY-FOR-PERFORMANCE

Business Week magazine ran a survey of compensation for company presidents. Salaries ranged from $350,000 to $8 million. In every case there was an extra "kicker" (a healthy bonus for achievement of certain goals in sales, profits, stock price, or the like). Despite gigantic salaries, every executive was offered an incentive bonus.

EXHIBIT TN4.14

Comparison of Common Reward/Incentive Plans

TYPE OF PLAN	APPLICATION	ADVANTAGES	DISADVANTAGES
Merit pay	Individual	• Allows management to target specific behavior and to easily evolve criteria over time.	• Can be arbitrary and unbiased when incorrectly administered. • Often not clearly tied to business goals.
Profit sharing	Group	• Ties business performance to employee reward.	• Often individual or group behavior is not correlated to business performance.
Gain sharing	Group	• Specific group performance directly tied to employee reward.	• Often focuses excessively on cost control. • More applicable for tactical improvements than strategic changes.
Lump-sum bonuses and individual bonuses	Either	• Allows management to vary criteria and magnitude of reward; able to target specific actions and behavior.	• Often used for and seen as deferred compensation. • Not always a tie to business goals or performance.
Pay-for-knowledge	Individual	• Allows management to target specific types of skills and personal growth.	• May not impact business performance unless management targets correct skills and applies new skills effectively.
Piece rate	Either	• Allows management to target specific output goals.	• May lead to undesirable competition among workers. • Standards must be kept up to date.

SOURCE: MODIFIED FROM C. GIFFI, A. ROTH, AND G. SEAL, *COMPETING IN WORLD-CLASS MANUFACTURING, AMERICA'S 21ST CENTURY CHALLENGE* (HOMEWOOD, IL: BUSINESS ONE IRWIN, 1990).

The following are more examples of incentive pay results:[7]

- At Kaiser Aluminum, located in Jackson, Tennessee, the use of incentive pay contributed to an 80 percent productivity boost over five years. Poor quality costs decreased by 70 percent.
- General Tire's 1,950-employee Mt. Vernon, Illinois, plant used a gain-sharing program to generate $30 million in savings over a five-year period, $20 million of which was paid out to workers in the form of bonuses. The company profited by $10 million.
- General Electric used a merit pay system to reduce its order-to-delivery time from 18 weeks to 5 weeks at its Louisville, Kentucky, appliance plant.
- Wrought Washer Manufacturing Company, located in Milwaukee, Wisconsin, improved productivity by 39 percent with a gain-sharing program. The workforce earned $165,737 in extra bonuses, and the company saved an additional $110,490.
- Whirlpool Corporation's Benton Harbor, Michigan, plant instituted a merit program. Over a period of eight years, the plant showed productivity gains of about 19 percent annually, with each year building on the previous year. Quality improvements have been substantial, with the number of parts rejected sinking to 4 per million from 837 per million.
- Finally, Jostens, a company that makes quality class rings, instituted a piece-rate system based on the number of good rings produced by each employee. Initially the company was producing 16 good rings per employee (deducting rejects and rework). After the program began, employees began producing 25 good rings per employee—a 56 percent productivity boost—with a lead time of 10 calendar days from work order to shipping. In only a year, productivity increased further to 36 good rings per employee.

The results of these studies are overwhelming. Paying employees based on their performance does work. Many experts, including those at the American Productivity and Quality Center, predict that these systems will become a common part of the strategy that companies employ to improve their performance in the 21st century.

CONCLUSION

At the outset of this technical note we identified current trends in job design. What will the future hold? One thing is clear: Globalization and the successful application of sophisticated process technologies will make the human element even more important to operations competitiveness than before. Giffi, Roth, and Seal speculate that "the 21st century will be marked by the human resource renaissance." In their view, this renaissance will be characterized by companies actively cultivating their human resources through careful selection and training of the best and brightest employees, implementing innovative team-based employee involvement programs, developing genuinely participative management approaches, and continually retraining their employees.[8] What is the future of the time study techniques also addressed in this technical note? In our opinion, they will always have application to analyzing work methods and, selectively, to setting work standards. Expectations concerning the time required to complete tasks form the basis for calculating capacity requirements and are a key input to labor planning activities.

KEY TERMS

Job design The function of specifying the work activities of an individual or group in an organizational setting.

Specialization of labor Simple, repetitive jobs are assigned to each worker.

Job enrichment Specialized work is made more interesting by giving the worker a greater variety of tasks or by getting a worker involved in planning, organization, and inspection.

Sociotechnical systems A philosophy that focuses more on the interaction between technology and the work group. The approach attempts to develop jobs that adjust the production process technology to the needs of the worker and work group.

Work physiology Considers the physical demands of a job. Work–rest cycles are set according to the energy expended on the job.

Ergonomics Study of the physical arrangement of the work space together with the tools used to perform a task.

Work measurement Job analysis for the purpose of setting time standards.

Time study Separation of a job into measurable parts, with each element timed individually. The individual times are then combined, and allowances are added to calculate a standard time.

Normal time The time that a normal operator would be expected to take to complete a job without the consideration of allowances.

Standard time Calculated by taking the normal time and adding allowances for personal needs, unavoidable work delays, and worker fatigue.

Work sampling Analyzing a work activity by observing an activity at random times. Statements about how time is spent during the activity are made from these observations.

FORMULA REVIEW

Standard time

[TN4.1] $$ST = NT(1 + \text{Allowances})$$ Assumes that allowances are added to normal time.

[TN4.2] $$ST = \frac{NT}{1 - \text{Allowances}}$$ Assumes that allowances are applied to the total work period.

SOLVED PROBLEMS

SOLVED PROBLEM 1

Brandon is very organized and wants to plan his day perfectly. To do this, he has his friend Kelly time his daily activities. Here are the results of her timing Brandon on polishing two pairs of black shoes using the snapback method of timing. What is the standard time for polishing two pairs? (Assume a 5 percent allowance factor for Brandon to put something mellow on the CD player. Account for noncyclically recurring elements by dividing their observed times by the total number of cycles observed.)

	Observed Times					
Element	1	2	3	4	Performance Rating	*NT*
Get shoeshine kit	0.50				125%	
Polish shoes	0.94	0.85	0.80	0.81	110	
Put away kit				0.75	80	

Solution

	ΣT	$\bar{T}$	Performance Rating	*NT*
Get shoeshine kit	.50	.50/2 = .25	125%	.31
Polish shoes (2 pairs)	3.40	3.40/2 = 1.70	110	1.87
Put away kit	.75	.75/2 = .375	80	.30
Normal time for one pair of shoes				2.48

Standard time for the pair = 2.48 × 1.05 = 2.60 minutes.

SOLVED PROBLEM 2

A total of 15 observations has been taken on a head baker for a school district. The numerical breakdown of the baker's activities is

Make Ready	Do	Clean Up	Idle
2	6	3	4

Based on this information, how many work-sampling observations are required to determine how much of the baker's time is spent in "doing"? Assume a 5 percent desired absolute accuracy and 95 percent confidence level.

Solution

To calculate the number of observations, use the formula at the bottom of Exhibit TN4.11 because the 95 percent confidence is required (that is, $Z \cong 2$).

$$p = \text{“Doing”} = 6/15 = 40\%$$

$$E = 5\% \text{ (given)}$$

$$N = \frac{4p(1-p)}{E^2} = \frac{4(.4)(1-.4)}{(.05)(.05)} = \frac{.96}{.0025} = 384$$

Review and Discussion Questions

1 Why might practicing managers and industrial engineers be skeptical about job enrichment and sociotechnical approaches to job design?

2 Professors commonly complain to their families that book writing is hard work and that they should be excused from helping out with the housework so that they can rest. Which exhibit in this chapter should they never let their families see?

3 Is there an inconsistency when a company requires precise time standards and encourages job enlargement?

4 Match the following techniques to their most appropriate application:

Worker–machine chart	Washing clothes at laundromat
Process chart	Tracing your steps in getting a parking permit
Work sampling	Faculty office hours kept

5 You have timed your friend, Lefty, assembling widgets. His time averaged 12 minutes for the two cycles you timed. He was working very hard, and you believe that none of the nine other operators doing the same job can beat his time. Are you ready to put forth this time as the standard for making an order of 5,000 widgets? If not, what else should you do?

6 Comment on the following:

a. "Work measurement is old hat. We have automated our office, and now we run every bill through our computer (after our 25 clerks have typed the data into our computer database)."

b. "It's best that our workers don't know that they are being time studied. That way, they can't complain about us getting in the way when we set time standards."

c. "Once we get everybody on an incentive plan, then we will start our work measurement program."

d. "Rhythm is fine for dancing, but it has no place on the shop floor."

7 Organizationwide financial incentive plans cover all the workers. Some units or individuals may have contributed more to corporate profits than others. Does this detract from the effectiveness of the incentive plan system? How would your incentive scheme for a small software development firm compare to an established auto manufacturing firm?

Problems

1. Correspondence to the guidelines for job design is an accurate predictor of the general level of subjective satisfaction.

1 Use the following form to evaluate a job you have held relative to the five principles of job design given in the chapter. Develop a numerical score by summing the numbers in parentheses.

	Poor (0)	Adequate (1)	Good (2)	Outstanding (3)
Task variety				
Skill variety				
Feedback				
Task identity				
Task autonomy				

a. Compute the score for your job. Does the score match your subjective feelings about the job as a whole? Explain.

b. Compare your score with the scores generated by your classmates. Is there one kind of job that everybody likes and one kind that everybody dislikes?

2 Examine the process chart in Exhibit TN4.5. Can you recommend some improvements to cut down on delays and transportation? (Hint: The research laboratory can suggest changes in the requisition form.)

2. See ISM.

3 A time study was made of an existing job to develop new time standards. A worker was observed for 45 minutes. During that period, 30 units were produced. The analyst rated the worker as performing at a 90 percent performance rate. Allowances in the firm for rest and personal time are 12 percent.
a. What is the normal time for the task?
b. What is the standard time for the task?
c. If the worker produced 300 units in an eight-hour day, what would be the day's pay if the basic rate was $6 per hour and the premium payment system paid on a 100 percent basis?

3. *a.* 1.35 minutes.
b. 1.51 minutes.
c. *ST* = 1.53 minutes.
The worker would not make the bonus. The pay is $48.

4 The Bullington Company wants a time standard established on the painting operation of souvenir horseshoes for the local Pioneer Village. Work sampling is to be used. It is estimated that working time averages 95 percent of total time (working time plus idle time). A co-op student is available to do the work sampling between 8:00 A.M. and 12:00 noon. Sixty working days are to be used for the study. Use Exhibit TN4.11 and an absolute error of 2.5 percent. Use the table of random numbers (Appendix B) to calculate the sampling schedule for the first day (that is, show the times of day that an observation of working/idle should be made). Hint: Start random number selection with the first tour.

4.

	Observation 1Times
(045)	8.45
(151)	9:51
(152)	9:52
(322)	11:22
(331)	11:31

5 The final result of the study in Problem 4 estimated working time at 91.0 percent. In a 480-minute shift, the best operator painted 1,000 horseshoes. The student's performance index was estimated to be 115 percent. Total allowances for fatigue, personal time, and so on are 10 percent. Calculate the standard time per piece.

5. Standard time = .558 minute.

6 Suppose you want to set a time standard for the baker making her specialty, square doughnuts. A work-sampling study of her on "doughnut day" yielded the following results:

6. *ST* = .078 min./doughnut.

Time spent (working and idle)	320 minutes
Number of doughnuts produced	5,000
Working time	280 minutes
Performance rating	125%
Allowances	10%

What is the standard time per doughnut?

7 In an attempt to increase productivity and reduce costs, Rho Sigma Corporation is planning to install an incentive pay plan in its manufacturing plant. In developing standards for one operation, time-study analysts observed a worker for 30 minutes. During that time the worker completed 42 parts. The analysts rated the worker as producing at 130 percent. The base wage rate of the worker is $5 per hour. The firm has established 15 percent as a fatigue and personal time allowance.
a. What is the normal time for the task?
b. What is the standard time for the task?
c. If the worker produced 500 units during an eight-hour day, what wages would the worker have earned?

7. *a.* *NT* = .9286 min./part.
b. *ST* = 1.0679 min./part.
c. Daily output = 449.50
Day's wages = $44.49.

8 Because new regulations will greatly change the products and services offered by savings and loan associations, time studies must be performed on tellers and other personnel to determine the number and types of personnel needed and incentive wage payment plans that might be installed. As an example of the studies that the various tasks will undergo, consider the following problem and come up with appropriate answers.

A hypothetical case was set up in which the teller (to be retitled later as an *account advisor*) was required to examine a customer's portfolio and determine whether it was more beneficial for the customer to consolidate various CDs into a single issue currently offered, or to leave the portfolio unaltered. A time study made of the teller yielded the following findings:

8. *a.* *NT* = 11.7 min.
b. *ST* = 13.455 min./portfolio.
c. Daily output at standard = 35.67; 50 portfolios, day's pay = $134.55.

Time of study	90 minutes
Number of portfolios examined	10 portfolios
Performance rating	130 percent
Rest for personal time	15 percent
Teller's proposed new pay rate	$12 per hour

a. What is the normal time for the teller to do a portfolio analysis for the CDs?
b. What is the standard time for the analysis?
c. If the S&L decides to pay the new tellers on a 100 percent premium payment plan, how much would a teller earn for a day in which he or she analyzed 50 customer portfolios?

9. Sample size = 933. Approximately 16 observations per day. See IM for example of sampling schedule.

9 Based on a manager's observations, a milling machine appears to be idle approximately 30 percent of the time. Develop a work-sampling plan to determine the percentage of idle time, accurate within a 3 percent error (±3%) with a 95 percent confidence level. Use the random numbers from Appendix B to derive the first day's sampling schedule (assume that the sample will take place over 60 days, and that an eight-hour shift is used from 8:00 to 12:00 and 1:00 to 5:00).

CASE: JEANS THERAPY—LEVI'S FACTORY WORKERS ARE ASSIGNED TO TEAMS, AND MORALE TAKES A HIT

In an industry notorious for low wages and lousy working conditions, Levi's has prided itself on being a grand exception. It offered generous pay plus plenty of charity support in factory towns—all financed by the phenomenal profitability of its brilliantly marketed brand name. It clung to a large U.S. manufacturing base long after other apparel firms began moving offshore, and it often was ranked among the best companies to work for.

But to many of Levi's workers, the company's image has not fit for some time. In 1992 the company directed its U.S. plants to abandon the old piecework system, under which a worker repeatedly performed a single, specialized task (like sewing zippers or attaching belt loops) and was paid according to the amount of work he or she completed. In the new system, groups of 10 to 35 workers would share the tasks and be paid according to the total number of trousers the group completed. Levi's figured that this would cut down on the monotony of the old system and enable stitchers to do different tasks, thus reducing repetitive-stress injuries.

At the time, the team concept was a much-touted movement designed to empower factory workers in many industries, and Levi's unions agreed to the effort. But there was more to it than that for Levi's. Faced with low-cost competitors manufacturing overseas, the San Francisco–based company did not feel it could keep many of its U.S. plants open unless it could raise productivity and reduce costs, particularly those incurred by injured workers pushing to make piecework goals. Teamwork, Levi's felt, would be more humane, safe, and profitable.

Instead, the new system led to a quagmire in which skilled workers found themselves pitted against slower colleagues, damaging morale and triggering corrosive infighting. Many top performers said the first thing they noticed about teams was that their pay shrank—and some of them decided to throttle back. They felt cheated because they were making less. Whenever a team member was absent, inexperienced, or just slow, the rest of the team had to make up for it. That infuriated some team members who felt they were carrying subpar workers. With limited supervision from coaches, groups were forced to resolve most workflow and personality issues themselves.

The fundamental problem arises from the nature of work at Levi's factories. Unlike an assembly line for cars or copiers, speed in garment-making relates directly to a worker's skill and stamina for grueling, repetitive motions of joining and stitching fabric. The workers in Levi's plants operate machines that perform specific tasks: pocket setter, belt looper, and fly stitcher, among others. Some employees work much faster than others.

In 1993 Levi's hired a consulting firm to analyze the problems. Its conclusion was simply that the company should start from scratch and involve all parties in a redesign of pay structures and work processes. As they began discussing the changes, some plant managers complained that the sessions were "at times too touchy-feely and not business-based enough." Some managers just did not like the idea of having sewing machine operators challenge their authority. Costs mounted, and in April 1994 plant managers were warned that they must cut costs by 28 percent on average by the end of 1997 or face an uncertain future.

By early 1997, Levi's share of the domestic men's denim jeans market fell to 26 percent from a high of 48 percent in 1990. Burdened by new debt, Levi's in February 1997 announced plans to cut its salaried workforce by 20 percent over 12 months. Later in November 1997, the firm announced the closing of 11 U.S. plants and layoffs of 6,395 workers. The company said that none of these jobs were transferred overseas. Still, over the years the company shifted much of its work abroad. Industrywide in 1991, approximately 15 percent of the jeans for the U.S. market were manufactured abroad. Approximately 45 percent of the jeans were produced in foreign plants by the end of 1997.

Levi's says the team approach was the company's attempt to ensure long-term survival for as many U.S. plants as possible. Plant closures might have come sooner, and job losses might have been heavier, had teams never been adopted, company officials say. Levi's vows to persevere with the team strategy at its remaining U.S. plants. But unofficially, much of the approach is being scrapped as individual managers seek ways to improve productivity. People in the plants are gradually going back to the old way of doing things.

QUESTIONS

1 What went wrong with Levi's move to teams in their plants?
2 What could Levi's have done differently to avert the problems?
3 Devise a team incentive plan that you think might work.
4 Do you think the need to move jeans production offshore was inevitable? Could Levi's have done anything to avert the problem of increasing labor costs?

SOURCE: R. T. KING JR., "JEANS THERAPY," *THE WALL STREET JOURNAL*, MAY 20, 1998, P. A1.

SELECTED BIBLIOGRAPHY

Meyers, F. E., and J. R. Stewart. *Time and Motion Study: For Lean Manufacturing.* 3rd ed. Upper Saddle River, NJ: Prentice Hall, 2001.

Niebel, B. W., and A. Freivalds. *Methods, Standards, and Work Design.* New York: WCB/McGraw-Hill, 1998.

Parker, S., and T. Hall. *Job and Work Design: Organizing Work to Promote Well-Being and Effectiveness.* Thousand Oaks, CA: Sage, 1998.

Ramsey, G. F., Jr. "Using Self-Administered Work Sampling in a State Agency." *Industrial Engineering,* February 1993, pp. 44–45.

Rutter, R. "Work Sampling: As a Win/Win Management Tool." *Industrial Engineering,* February 1994, pp. 30–31.

Sasser, W. E., and W. E. Fulmer. "Creating Personalized Service Delivery Systems." In *Service Management Effectiveness,* ed. D. Bowen, R. Chase, and T. Cummings. San Francisco: Jossey-Bass, 1990, pp. 213–33.

FOOTNOTES

1 E. E. Lawler III, *The Ultimate Advantage: Creating the High Involvement Organizations* (San Francisco: Jossey-Bass, 1992), pp. 85–86.

2 Ibid., pp. 98–99.

3 This summary is taken from E. Mumford and M. Weir, *Computer Systems in Work Design—the ETHICS Method* (New York: Halstead, 1979), p. 42.

4 For a complete discussion of incentive plans, including quality measures, see S. Globerson and R. Parsons, "Multi-Factor Incentive Systems: Current Practices," *Operations Management Review* 3, no. 2 (Winter 1985).

5 C. O'Dell, *People, Performance, and Pay* (Houston: American Productivity Center, 1987).

6 E. E. Lawler III, "Paying for Organizational Performance," Report G87-1(92) (Los Angeles: Center for Effective Organizations, University of Southern California, 1987).

7 These examples are from W. Imberman, "Pay for Performance Boosts Quality Output," *Industrial Engineering,* October 1996, p. 35.

8 C. Giffi, A. Roth, and G. M. Seal, *Competing in World-Class Manufacturing: America's 21st Century Challenge* (Homewood, IL: Richard D. Irwin, 1990), p. 299.