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BUS 801

Operations Management

Module 4

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Module 4

Unit 1 Work Methods

1.0 Introduction

In this unit, you will learn that methods analysis and motion study techniques are often used to develop the "efficiency" aspects of job. However they do not directly address their behavioural aspects. Nonetheless, they are important part of job design, as well as the efforts being made to increase productivity through different means.

2.0 Objectives

At the end of this unit, you should be able to:

- explain the importance of work methods analysis
- demonstrate the ability to develop a questioning attitude about every aspect of a particular job to be studied
- explain the steps usually followed by job analysis
- explain who a job analyst is
- demonstrate how to use motion study in the performance of human activities
- demonstrate the ability to use flow diagrams and process charts.

3.0 Main Content

3.1 Introduction to Work Methods Study

It is usual for job design to begin with a methods analysis of an overall operation. It then moves from general to specific details of the job by concentrating on arrangement of the workplace and movements of the worker.

The need for methods analysis can come from a number of different sources, such as:

a. Changes in tools and equipment

b. Changes in product design, or new products

c. Changes in materials or procedures

d. Government regulations or contractual agreements

e. Other factors (e.g. accidents, quality problems)

In our treatment of Productivity and Human Behaviour under Unit 15, we referred to Figure 15.1, showing the various variables affecting labour productivity. From that figure, you were able to see that the machines, tools, materials, and work methods used by workers directly affect labour productivity. How do we go about improving work methods? It might be better to start with workers themselves. This is because they are the people who do the jobs daily, and on things related to these jobs. In a way, they are experts in their own rights.

You should note that the main objective of improving work methods is to increase productivity by increasing the production capacity of an operation or group of operations, reducing the cost of the operations, or improving product quality. One important approach to successful methods analysis is the development of a questioning attitude about every aspect of the job being studied. Such relevant questions will include the following:

i. Why is there a delay or storage at this point?

ii. How can travel distances be shortened or avoided?

iii. Can materials handling be reduced?

iv. Would a re-arrangement of the workplace result in greater efficiency?

v. Can similar activities be grouped?

vi. Would the use of additional or improved equipment be helpful?

vii. Does the worker have any ideas for improvement?

viii. Who else could do it better?

Questions such as these will ensure that analysts accept nothing in an operation as sacred, i.e. everything about the job will be meticulously scrutinized.

3.2 Steps Involved in Conducting Work Methods

Works analysis can be done both for existing jobs and jobs that have not yet been performed. It might seem strange to you that we are talking about analysing methods of nonexisting jobs! Yet, it is important to establish a method for a new job, instead of allowing the job to start and then try to improve it later.

For an existing job, the procedure usually is to have the analyst observe the job as it is currently being performed, and then device improvements. For a new job however, the analyst must rely on a job description and an ability to visualise the operation in advance.

Gaither (1996) lists ten steps that are generally followed by methods analysts:

i. Make an initial investigation of the operation under consideration

ii. Decide what level of analysis is appropriate

iii. Talk with workers, supervisors, and others who are familiar with the operation. Get their suggestions for better ways to do the work.

iv. Study the present method. Use process Charts, time study, and other appropriate techniques of analysis. Thoroughly describe and evaluate the present method

v. Apply the questioning attitude, the principles of motion economy, and the suggestions of others. Device a new proposed method by using process charts and other appropriate techniques of analysis.

vi. Use time study, if necessary. Compare new and proposed methods. Obtain supervisors' approval to proceed.

vii. Modify the proposed method as required after reviewing the details with workers and supervisors.

viii. Train one or more workers to perform the proposed method on a trial basis. Evaluate the proposed method. Modify the method as required.

ix. Train workers and install the proposed method.

x. Check periodically to ensure that the expected savings are being realised.

In performing work methods analysis, certain diagrams and charts can be useful. These include flow-process charts and worker-machine charts.

3.2.1 Flow-Process Charts

Flow diagrams and process charts are about the most versatile techniques available for analysing work methods. They are usually used together to eliminate or reduce delays, eliminate or combine tasks, or reduce travel time or distance. Table 16.1 shows and describes widely applied flowcharting symbols. Of the five, only the operation symbol denotes a value-adding activity. The other symbols reflect an addition of cost not value.

Table 16.1: Flow Chart Symbols

Symbol	Activity	Description
●	Operation	Activity that adds value to a workplace or provides a value-adding service to a customer; usually Operation requires a setup
→	Transportation	Movement of objects from one work station to another; movement of customer from one operation Transportation to another
■	Inspiration	Work is checked for some characteristic of quality; may call for 100 - percent inspection or inspection by sampling
▼	Storage	Applies to materials or documents; may be Storage temporary, or permanent V
D	Delay	Time, person, materials or documents wait for next operation; In lot delay, wait is for other items in the lot to be processed; In process delay, entire lot waits for workstation or other bottleneck to clear

Figure 16.1 shows how an improvement team might document a company's travel authorisation process. The before version, i.e. part A, has eight value-adding operations, five transportations, two inspections, and three delays. The streamlines version in part B uses personal computer communication by e-mail. It thus cuts the operations to five, transportation to two, inspections to one (combined with an operation), and delays to one. You should, however, note that the reduction from eight to five does not mean less value, since value-adding operations also consume costly resources and time. The end result is a simpler process that does the job.

For worked examples on this discussion please refer to Dennis C. Kinlaw (1992) Continuous Improvement and Measurement for Total Quality (Burr Ridge, III, Business One Irwin, 1992), pp. 214-215.

3.2.2 Worker-machine Chart

A worker-machine chart is helpful in visualising the portions of a work cycle during which an operator and equipment are busy or idle. The analyst can easily see when the operator and machine are working independently, and when their work overlaps or is interdependent. One area in which this type of chart is useful is in determining how many machines or how much equipment the operator can manage. An example of a worker machine chart is given in Figure 16.2.

Product; Operator;

Process; Charted by;

Stop	Employee	time (Seconds)	machine
1	Accept plastic bag from customers and places on scale	0 1	
2	punches in price/b	2 3	
3			
4	Removes bag	6	
5	Note prices and makes on bag	7	
6	Hands bag to customer	8	

Summary

4 calculate and display total
5 price

	Employee Time (Seconds)	%	Machine Time (Second)	%
Work	7	87.5	1	12.5
Idle	1	12.5	7	87.5

Figure 16.2: Worker-Machine Chart

Source: Adapted from Schroeder, R.G. (1993). *Operations Management Decision Making in the Operations Function* (4th ed.). New York: McGraw-Hill

3.3 Motion Study

Motion study is the systematic study of human motions used during the performance of an operation. The purpose is to eliminate unnecessary motions and to identify the best sequence of motions for maximum efficiency. In this regard therefore, motion study can be an important avenue for productivity improvements. The present practice of motion study can be traced to the work of Frank Gilbreth, who originated the concept in the bricklaying trade in the early 20th century.

There are a number of different techniques that motion study analysts can use to develop efficient procedures. We will only review motion study principles and micromotion study here.

3.3.1 Motion Study Principles

Gilbreth's work laid the foundation for the development of motion study principles, which are guidelines for designing motion-efficient work procedures. The guidelines are divided into three categories: principles for use of the body, principles for arrangement of the workplace and principles for the design of tools and equipment. These principles are listed in Table 16.2.

Table 16.2: Motion Study Principles

1. Finger motions.
2. Finger and wrist motions.
3. Finger, wrist, and lower arm motions.
4. Finger, wrist, lower arm, and upper arm motions.
5. Finger, wrist, lower arm, upper arm, and body motions.
6. Work done by the feet should be done simultaneously with work done by the hands. However, it is difficult to move the hand and foot simultaneously.
7. The middle finger and the thumb are the strongest. The use of the human body:

(a) Both hands should begin and end their basic divisions of accomplishment simultaneously and should not be idle at the same instant, except during rest periods.

(b) The motions made by the hands should be made symmetrically and simultaneously away from and toward the center of the body.

(c) Momentum should assist workers wherever possible and should be minimized if it must be overcome by muscular effort.

(d) Continuous curved motions are preferable to straight-line motions involving sudden and sharp changes in direction.

(e) The least number of basic divisions should be used, and they should be confined to the lowest practicable classifications. These classifications, summarized in ascending order of the time and fatigue expended in their performance are: working fingers. The index finger, fourth finger, and little finger are not capable of handling heavy loads over extended periods.

8. The feet are not capable of efficiently operating pedals when the operator is in a standing position.

9. Twisting motions should be performed with the elbows bent.

10. To grip tools, workers should use the segments of the fingers closest to the palm of the hand.

The arrangements and conditions of the workplace

1. Fixed locations for all tools and material should be provided to permit the best sequence and to eliminate or reduce the therbligs search and select.

2. Gravity bins and drop delivery should reduce reach and move times, wherever possible, ejectors should remove finished parts automatically.

3. All materials and tools should be located within the normal working area in both the vertical and the horizontal planes.

4. A comfortable chair for the operator and the workstation's height should be arranged so that the work can be efficiently performed by the operator alternately standing or sitting.

5. Proper illumination, ventilation, and temperature should be provided.

6. The visual requirements of the workplace should be considered so that eye fixation demands are minimized.

7. Rhythm is essential to the smooth and automatic performance of an operation, and the work should be arranged to permit an easy and natural rhythm wherever possible.

The design of tools and equipment

1. Multiple cuts should be taken whenever possible by combining two or more tools in one or by arranging simultaneous cuts from both feeding devices, if available (cross slide and hex turret).

2. All levers, handles, wheels, and other control devices should be readily accessible to the operator and designed to give the best possible mechanical advantage and to utilize the strongest available muscle group.

3. Parts should be held in position by fixtures.

4. The use of powered or semi automatic tools, such as power nut and screwdrivers and speed wrenches, should always be investigated.

Source: Adapted from Benjamin Niebel, W. (1993). *Motion and Time Study*. Burr Ridge, III: Richard D. Irwin, Inc., pp. 206-207.

In developing work methods that are motion-efficient, the analyst tries to:

1. Eliminate unnecessary motions
2. Combine activities
3. Reduce fatigue
4. Improve the arrangement of the workplace
5. Improve the design of tools and equipment.

3.3.2 Micromotion Study

Frank Gilbreth and his wife, Lilian (an industrial psychologist) were also responsible for introducing motion pictures for studying motions, called micromotion study.

Apart from its direct application in the industry, micromotion study is now useful in other human endeavours such as sports and health care. The use of video camera and slow-motion replays enable analysts to study motions that would otherwise be too rapid to see. Today, it is a most important tool in sports administration, coaching, and arbitration in disputed competitions. It is also increasingly being used to analyse crimes. One other important advantage of micromotion study is that the resulting films provide a permanent record that can be referred to, not only for training workers and analysts, but also for settling job disputes involving work methods.

4.0 Conclusion

The best way to improve work methods is to start with workers. This is because they are the people who do the jobs daily, and on things related to these jobs. The main objective of work methods is to increase productivity by increasing the production capacity of an operation or group of operations, reducing the cost of the operation or improving product quality.

5.0 Summary

Methods analysis and motion study techniques are often used to develop the "efficiency" aspects of jobs. However, they do not address their behaviour aspects. In spite of this, they are some important parts of job design. Working conditions are also important aspects of job design, not only because of the behavioural and efficiency factors, but also because of concern for the health and safety of workers.

6.0 Self-Assessment Exercise

1. Wherever work is been done, methods study is a desirable process. How do you understand:

a) Work methods

b) Motion Study

c) Mocromotion

2. What would you do in an attempt to develop work methods that are motion efficient?

3. Explain the uses of worker-machine chart.

7.0 References/Further Reading

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Unit 2 Work Measurement

1.0 Introduction

In Unit 5, you learned that job design determines the content of a job. This unit is devoted to work measurement, which is the process of creating labour standards based on the judgment of skilled observers. Actually, job times are vital inputs for manpower planning, estimating labour costs, scheduling, budgeting and designing incentive systems.

2.0 Objectives

At the end of this unit, you should be able to:

- define a standard time
- discuss and compare time study methods
- describe work sampling and perform calculations
- compare stopwatch time study and work sampling.

3.0 Main Content

3.1 Relevance of Work Measurement

Work measurement refers to the process of estimating the amount of worker time required to generate one unit of output. Its ultimate goal is usually to develop labour standards that will be used for planning and controlling operations, thereby achieving labour productivity.

Job times are important inputs for manpower planning, estimating labour costs, scheduling, budgeting, and designing incentive systems. In addition, from the workers' standpoint time standards provide an indication of expected output. Time standard reflects the amount of time it should take an average worker to do a given job, working under typical conditions. The standards include expected activity time plus allowances for probable delays. Whenever a time standard is developed for a job, it is essential to provide a complete description of the parameters of the job because the actual time to do the job is sensitive to given methods, tools and equipment, raw materials inputs and workplace arrangement. For instance, changes in product design or changes in job performance brought about by a methods study should necessitate a new time study to update the standard time.

3.2 Standard Time as Management Tool

Managers use Standard Time in the following ways:

(i) Establishing Prices and Costs: Managers can use labour and machine time standards to develop costs for current and new products, create budgets, determine prices and arrive at make or - buy decisions.

(ii) Motivating Workers: Standards can be used to define a day's work or to motivate workers to improve their performance. For example, under an inventive compensation plan, workers can earn a bonus for output that exceeds the standard.

(iii) Comparing alternative process designs: Time standards can also be used to compare different routings for an item and to motivate new work methods and new equipment.

(iv) Scheduling: Managers need time standards to assign task to workers and machines in ways that effectively utilize resources.

(v) Capacity Planning: Managers can use time standards to determine current and projected capacity requirements for given demand requirements. Work-force staffing decisions also, may require time estimates.

(vi) Performance Appraisal: A worker's output can be compared to the standard output over a period of time in order to evaluate worker performance and productivity. A manager's performance can similarly be measured by comparing actual costs to standard costs of a process.

3.3 Methods of Work Measurement

Organisations develop time standard in a number of different ways. The most common methods of work measurements are:

(i) The time study method

(ii) The elemental standard data approach

(iii) The predetermined data approach and

(iv) The work sampling method.

The particular method chosen usually depends on the purpose of the data. For example, if a high degree of precision is needed in comparing actual work method results to standard, a stopwatch study or pre-determined times might be required. On the other hand, an analyst who wants to estimate the percentage of time that an employee is idle while waiting for materials requires a work sampling method. We shall be examining the time study method, elemental standard data approach, and the work sampling method in the sections that follow.

3.3.1 Time Study Method

In this method, analysts use stopwatches to time the operation being performed by workers. These observed times are then converted into labour standards that are expressed in minutes per unit of output for the operation.

A time study usually consists of four steps:

Step 1: Selecting Work Elements

Each work element should have definite starting and stopping points so as to facilitate taking stopwatch readings. It has been suggested that work elements that take less than three seconds to complete should be avoided since they are often difficult to time.

The work element selected should correspond to a standard work method that has been running smoothly for a period of time in a standard work environment. Efforts should also be made to identify and separate incidental operations that are not normally involved in the task from the repetitive work.

Step 2: Timing the Elements

Here, the analyst times a worker trained in the work, in order to get an initial set of observations. The analyst may use either the continuous method, recording the stopwatch reading for each work element upon its completion, or the snap-back method, re-setting the stopwatch to zero upon completion of each worker element.

In the case of the latter, the analyst uses two watches, one for recording the previous work element, and the other for timing the present work elements.

In case that data include a single, isolated time that differs greatly from other times recorded for the same element, it is advisable for the analyst to investigate the cause of the variation. Any irregular occurrence such as a dropped tool or a machine failure, should not be included in calculating the average time for the work element. The average observed time based only on representative times is called the select time (t).

Step 3: Determining Sample Size

It is usual for analysts using the time study method to look for an average time estimate that is very close to the true long range average most of the time. The following formular, based on the normal distribution is used to determine the required sample size, n:

$$n = \left[\left(\frac{Z}{P}\right)\left(\frac{\delta}{t}\right) \right]^2$$

Where

n = required sample size

P = precision of the estimate as a proportion of the true value

t = select time for a work element

δ = standard deviation of representative observed times for a work element.

Z = number of normal standard deviations needed for the desired confidence.

Where = Accuracy or maximum acceptable error Typical values of Z for these formulars are:

Desired Confidence (%)	Z
90	1.65
95	1.96
96	2.05
97	2.17
98	2.33
99	2.58

For example, a Z value of 1.96 represents ±1.96 standard deviations from the mean, leaving a total of 5 percent in the tails of the standardized normal curve. The precision of the estimate, P is expressed as a proportion of the true (but unknown) average time for the work element.

Let us make use of an example given by Krajewski and Ritzman (1999) as an illustration of this step.

The example

A coffee cup packaging operation has four work elements. A preliminary study provided the following results:

Work Element	Standard deviation, δ (minutes)	Select Time, t (minutes)	Sample size
1. Get two cartons	0.0305	0.50	5
2. Put liner in carton	0.0171	0.11	10
3. Place cups in carton	0.0226	0.71	10
4. Seal carton and set	0.0241	1.10	10

Aside

Work element 1 was observed only 5 times because it occurs once every two work cycles. The study covered the packaging of 10 cartons. Determine the appropriate sample size if the estimate for the select time for any work element is to be within 4 percent of the true mean 95 percent of the time.

Solution

For this problem

P= 0.04 and Z = 1.96

The sample size for each work element must be calculated, and the largest must be used for the final study so that all estimates will meet or exceed the desired precision.

Work Element 1: $$n = \left(\frac{1.96}{0.04}\right)\left(\frac{0.0305}{0.5000}\right) = 9$$

Work Element 2: $$n = \left[\left(\frac{1.96}{0.04}\right)\left(\frac{0.0171}{0.11}\right)\right]^2 = 58$$

Work Element 3: $$n = \left[\left(\frac{1.96}{0.04}\right)\left(\frac{0.0226}{0.71}\right)\right]^2 = 3$$

Work Element 4: $$n = \left[\left(\frac{1.96}{0.04}\right)\left(\frac{0.0241}{1.10}\right)\right]^2 = 2$$

All fractional calculations were rounded to the next largest integer. To be sure that all select times are within 4 percent of the true mean 95 percent of the time, we must have a total of 58 observations because of work element 2. Consequently, we have to observe the packaging of 48 (i.e. 58-10) more cartons.

Step 4: Setting the Standard

This is the final step. Here, the analyst first determines the normal time for each work element by judging the pace of the observed worker. Next, he assesses not only whether the pace is above or below average, but also a performance rating factor (RF) that describes how much above or below average the worker's performance on each element is. Note that setting the performance rating requires the greatest amount of judgment. Usually, only a few workers are observed during a study. If the workers are fast, basing the standard on their average time wouldn't be fair, especially if a wage incentive plan is involved. At the same time, If the workers are slow, basing the standard on their normal time would be unfair to the company. In addition, workers may slow pace when they are being observed in a time study. Ironically, it is important to inform the observed worker about the study, so as to avoid suspicion or misunderstandings.

Workers sometimes feel uneasy about being studied and fear the changes that might result. It is therefore necessary for the analyst to discuss these things with the workers prior to studying the operation to allay such fears, and to enlist the cooperation of the worker. Due to these apparent distractions, the analyst has to make an adjustment in the average observed time to estimate the time required for a trained operator to do the task at a normal pace.

The analyst must also factor in the frequency of occurrence, F, of a particular work element in a work cycle. The normal time (NT) for any work element is calculated by multiplying the select time (t), the frequency (F) of the work element per cycle, and the rating factor, (RF) i.e.:

$$NT = t(F)(RF)$$

NOTE: Use F= 1, if the work element is performed every cycle

F= 0.05, if it is performed every other cycle. etc.

To find the normal time for the cycle (NTC) the normal time for each element is summed up. i.e. NTC = ΣNT,

Where Σ = sum of

An Example of the determination of the Normal Time

Suppose that 48 additional observations of the coffee packaging operations earlier referred to, were taken and the following data were recorded.

Work Element	t	F	RF
1	0.53	0.50	1.05
2	0.10	1.00	0.95
3	0.75	1.00	1.10
4	1.08	1.00	0.90

Because element 1 occurs only every other cycle, its average time per cycle, must be half its average observed time. That is why Fl = 0.50 for that element. All others occur every cycle. What are the normal times for each work element, and for the complete cycle?

Solution

The normal times are calculated as follows:

Work element 1	NT1 = 0.53(0.50)(1.05)	=	0.28 minute
Work element 2	NT2 = 0.10(1.00)(0.95)	=	0.10
Work element 3	NT3 = 0.75(1.00)(1.10)	=	0.83
Work element 4	NT4 = 1.08 (1.00)(0.90)	=	0.97
	TOTAL	2.18 minutes	

The normal time for the complete cycle is 2.18 minutes.

Note that it is not realistic to use this normal time of 2.18 minutes for the cycle as a standard. Can you guess why? This is because it doesn't allow for fatigue, rest periods, or unavoidable delays that might have occurred during an average work day. Therefore, we need to add some allowance time to the normal time to adjust for these factors. The standard time (ST) therefore becomes.

ST = NTC (1 +A)

Where A = Proportion of the normal time added for allowances.

Most allowances range from 10 to 20 percent of normal time and cover factors that may be difficult to measure. However, work sampling can be used to estimate some of those factors. Below is an example of the determination of Standard Time.

Management needs a standard time for the Coffee package operation. Suppose that A= 0.15 of the normal time. What is the standard time for the coffee cup packaging operation, how many cartons can be expected per eight hour day?

Solution

For A = 0.15 of the normal time,

ST = 2.18 (1+0.15) = 2.51 minutes/carton

For an 8-hour day, this translates into a production standard of 480 minutes/day

2.51 minutes/carton = 191 cartons/day A useful hint

At times, you might not be given the value of the standard deviation, •, but would then

compute it from sample data. This you can do, using this formular:

$$\sqrt{\sum Xi2 - (\sum Xi)^2/n}$$

= Standard Deviation

3.3.1.1 An Assessment of Time Study

Time study methods have been observed to have some limitations. Therefore, it is suggested that they should not be used to set standards for jobs in which the nature of the task is different each time.

Examples of the situation above include a student solving a problem, a professor preparing a lecture, or an automobile mechanic diagnosing the cause of a non-routine problem. Furthermore, an inexperienced person should not be allowed to conduct time studies because errors in recording information or in selecting the work elements to include can result in unrealistic standards.

Another limitation of the time study is that some workers may object to it because of the "subjectivity" involved.

However, in spite of the above shortcomings, time studies conducted by an experienced analyst usually provide a satisfactory, although imperfect, tool for setting equitable time standards.

3.3.2 Elemental Standard Data Approach

Standard elemental times are derived from a firm's own historical time study data. For instance, a time study department over the years might have accumulated a file of elemental times that are common to many jobs. After a certain point, many elemental times can be simply retrieved from the file, thus eliminating the need for analysts to go through a complete time study to obtain them.

The procedure for using standard elemental times consists of the following steps:

(i) Analyse the job to identify the standard elements

(ii) Check the file for elements that have historical times and record them, use time study to obtain others, if necessary

(iii) Modify the file times if necessary. Let us look at some cases where the file times may not pertain exactly to a specific task. For instance, standard elemental times might be on file on "move the tool 3 centimeters" and "move the tool 9 centimeters", whereas the task in question involves a move of 6 centimeters. What can possibly be done is to interpolate between values on file to obtain the desired time estimate.

(iv) Sum the elemental times to obtain the normal time, and factor in allowances to obtain the standard time.

3.3.2.1 An Assessment of the Elemental Standard Data Approach

An obvious advantage of the elemental standard data approach is the potential savings in cost and effort created by not having to conduct a complete time study for each job.

Secondly, there is less disruption of work, since the analyst does not have to time the worker. Thirdly, performance ratings do not have to be done, since they have been generally averaged in the file times.

However, the elemental standard data approach suffers from a major limitation in that times may not exist for enough standard elements to make it worthwhile. In addition, the file times may be biased or inaccurate.

3.3.3 Work Sampling Method

Work sampling is a work measurement technique that randomly samples the work of one or more employees at periodic intervals to determine the proportion of the total operation that is accounted for in one particular activity.

These types of studies are frequently used to estimate the percentage of employee's time spent in such activities as:

- Unavoidable delays, which are commonly called ratio-delay studies;
- Repairing finished products from an operation; or
- Supplying material to an operation

The results of these studies are commonly used to set allowances used in computing labour standards, in estimating costs of certain activities, and in investigating work methods. Unlike time study, work sampling does not require timing an activity nor does it even involve continuous observation of the activity. Instead, an observer is required to make brief observations of a worker or machine at random intervals over a period of time and simply note the nature of the activity. For example, a machine may be busy or idle; a secretary may be typing, filing, talking on the phone, etc. The resulting data are counts of the number of times each category of activity or non-activity was observed.

Conducting a work sampling study involves the following steps:

(i) Define the activities

(ii) Design the observation form

(iii) Determine the length of the study

(iv) Determine the initial sample size

(v) Select random observation times using a random number table

(vi) Determine the observer table schedule

(vii) Observe the activities and record the data

(viii) Decide whether additional sampling is required.

It is important to note here, that work sampling estimates include some degree of error. For instance, the same number of observations taken at different times during the week will probably produce slightly different estimates, and all estimates will usually differ from the actual (but unknown) values. It is therefore important to treat work sampling estimates as approximations of the actual proportion of time devoted to a given activity.

3.3.3.1 Sample Size

The goal of work sampling is to obtain an estimate that provides a specified confidence not differing from the true value by more than a specified error. That is, we want to take a sample, calculate the sample proportion, and be able to say that the following interval contains the true proportion with a specified degree of precision:

Where, $\hat{P} - e < \hat{P} < \hat{P} + e$

$\hat{P}$ = Sample proportion (number of occurrence divided by the sample size)

e = maximum error in the estimate.

The surface size affects the degree of precision that can be expected from work sampling for any desired level of statistical confidence. Since work sampling involves estimating proportions, its sampling distribution is the binomial distribution. However, it has been found that since large sample sizes are required for this approach, the normal approximation to the binomial distribution can be used to determine the appropriate sample size. Figure 17 shows the confidence interval for a work sampling study. The maximum error can be computed as:

$$e = Z\sqrt{\frac{\hat{P}(1-\hat{P})}{n}}$$

Where n = sample size

Z = number of standard deviations needed to achieve the desired confidence.

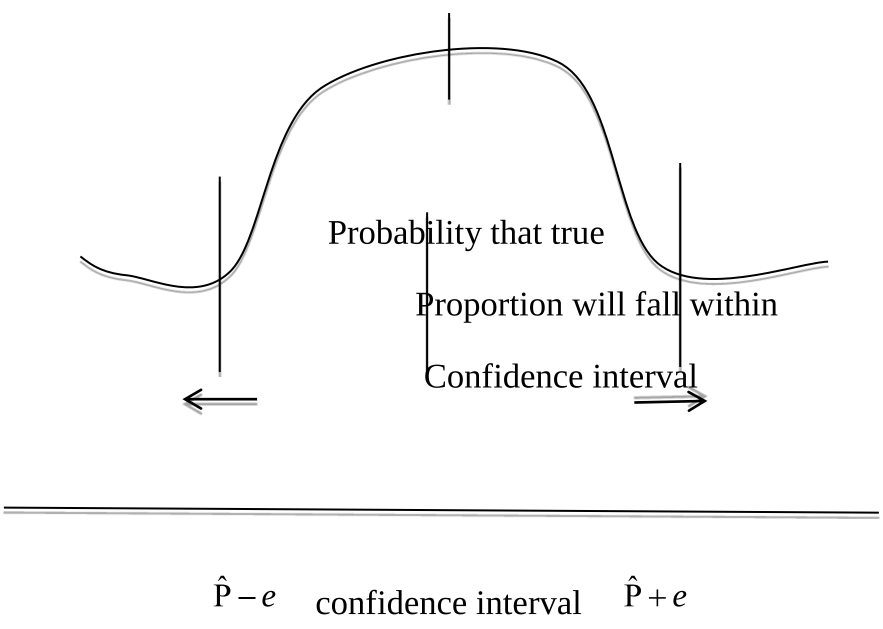


Figure 11.1: Confidence interval for a Work Study Sampling

An Example of the calculation of Sample Size

The manager of a small supermarket chain wants to estimate the proportion of time stock clerks spend making price changes on previously marked merchandize. The manager wants a 98 percent confidence that the resulting estimate will be within 5 percent of the true value. What sample size should he use?

Solution

e= 0.05(given)

Z = 2.33 (i.e. from z values, 98% confidence interval yields a z-value of 2.33

$\hat{P}$ is unknown.

When no sample estimate of P is available, a preliminary estimate of sample size can be obtained using $\hat{P}$ = 0.50. After 20 or so observations, a new estimate of $\hat{P}$ can be obtained from the observations and a revised value of n computed using the new $\hat{P}$ It is better to recompute the value of n at two or three points during the study to obtain a better indication of the necessary sample size.

The required sample site for the given information can be computed by the formular: n = $\frac{Z^2\left[\hat{P}(I-\hat{P})\right]}{e^2}$

The required sample site for the given information can be computed by the formular:

$$n = \frac{Z^2\left[\hat{P}(I-\hat{P})\right]}{e^2}$$

Thus, n = (2.33) [0.05(1-0.05)] $\frac{[0.05(1-0.05)]}{(0.25)^2}$

$$= \frac{5.43(0.25)}{0.0025} = 543$$

It follows that the manager should use a sample size of 543.

4.0 Conclusion

Through this unit, you have learned that it is important for management to make design of work systems a key element of its operations strategy. Work measurement is the process of estimating the amount of worker time required to generate one unit of output. Its ultimate goal is usually to develop and controlling operations, thereby achieving high labour productivity.

5.0 Summary

As already mentioned above, work measurement is concerned with specifying the length of time needed to complete a job. Such information is vital for personnel planning, cost estimating, budgeting, scheduling, and worker compensation. Commonly used approaches include stopwatch time study and predetermined times.

6.0 Self-Assessment Exercise

1. How does work measurement contribute to the operation of a modern industrial concern?

2. Comment on suitability of work sampling to set time standards on maintenance operations.

7.0 References/Further Reading

Adam, E.E. J.; *et al* (1981). Productivity and Quality: *Measurement as a Basis.* For Improvement. Englewood Cliffs. NJ: Prentice-Hall.

Karger, D.W. (1982). *Advanced Work Measurement.* New York: Industrial Press.

Unit 3 Learning Curves

1.0 Introduction

This unit is in continuation of our study on productivity improvement. From the previous units, you have learned what productivity means, and how it can be improved. You were also taken through such relevant areas as job design, work methods study, and work measurement. This present topic is on learning curves, which displays the relationship between the total direct labour per unit and the cumulative quantity of a product or service produced. You will find the topic quite interesting and rewarding as specified in the study objectives.

2.0 Objectives

At the end of this unit, you should be able to:

- explain the concept of a learning curve and how volume is related to unit costs
- develop a learning curve, using the arithmetic and logarithmic analyses
- demonstrate how to use the learning-curve table
- demonstrate the use of learning curves for managerial decision making.

3.0 Main Content

3.1 A Soft Background to Learning and the Experience Curve

We are going to open the discussion on learning curve with a soft, or if you like, elementary prologue:

When anybody starts something new, there is a form of learning process before one arrives at one's optimum ability. For instance, in the life cycle, one learns to walk; one learns to talk; one learns to study; one learns in a professional environment, etc. Another fact we should note is that some activities are harder to learn than others, while some individuals are quicker to learn than others.

Let us use some examples to explain the concept of the learning curve: If a company develops a new product, or process, it usually takes time for engineers, operators and/or maintenance personnel to understand the process, as well as the design fully, and thus be efficient regarding all the activities involved. Because of this, the operating and/or product costs at the early stages are higher than at the later periods. Similarly, it takes time for new employees to become full operational in a company that already has established programmes and procedures in place.

The point being made is that human performance of activities typically shows improvement when the activities are done on a repetitive basis. That is, the time required to perform a task decreases with increasing repetitions. Learning curves seem to summarise this phenomenon. However, the degree of improvement and the number of tasks needed to realise the major portion of the improvement is a function of the task being done. For instance, if the task is short and somewhat routine, only a modest amount of improvement is likely to occur, and it generally occurs during the first few repetitions. If the task is fairly complex and has a longer duration, improvements will occur over a longer interval (i.e, larger number of repetitions). Hence learning factors have little relevance for planning or scheduling routine activities, but they do have relevance for complex repetitive activities.

Figure 18.1 illustrates the basic relationship between increasing repetitions and a decreasing time per repetition. You should note that the curve will never touch the horizontal axis, i.e., the time per unit will never be zero.

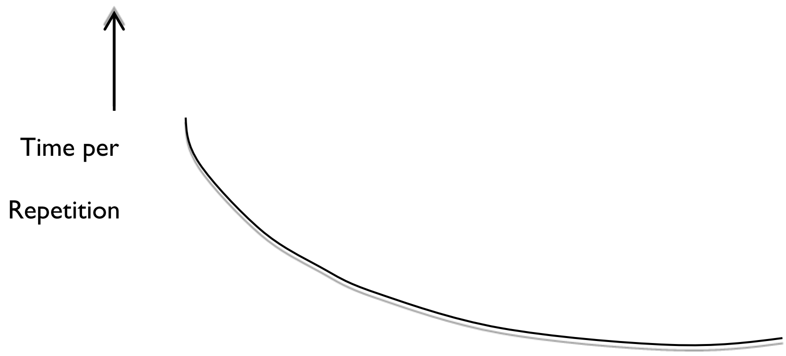


Figure 18.1: The Learning Effect: Time per Repetition Decreases as the Number of Repetitions increase

3.2 The Learning Curve

The experience, or learning curve, sometimes called the manufacturing progress function, is a mathematical relationship between the cumulative production output and its cost, expressed either in financial terms or in production. The learning curve was first developed in the aircraft industry prior to World War II, when analysts discovered that the direct labour input per airplane decline with considerable regularity as the cumulative number of planes produced increased. Subsequent survey of major airplane manufacturers revealed that a series of learning curves could be developed to represent the average experience for various categories of airframes (e.g. fighters, bombers, etc), despite the different amount of time required to produce the first unit of each type of airframe. It was found that once production started, this direct labour for the eight unit was only 80 percent of that for the fourth unit, the direct labour for the twelfth was only 80 percent of that for the sixth etc. In each case, each doubling of the quantity reduced production time by 20 percent. It was thus concluded that the aircraft industry's rate of learning was 80 percent between doubled quantities of airframe due to the consistency in the observed rate of improvement.

In other words, the labour-hours required to assemble an aircraft is reduced by a factor of 0.8 as the production quantity is doubled. Figure 18.2 shows how the learning of workers causes the labour-hours per unit to fall as the number of unit produced increases. For example, if the first aircraft assembled requires 100 labour-hours, the second aircraft would require 0.8 x 100 = 80 labour-hours, the fourth would require 0.8 x 80 = 64 labour-hours, the eight would require 0.8 x 64 = 51.2 labour-hours etc.

3.3 Mathematical Representation of Learning Curve

A mathematical learning curve can be developed by plotting production labour-hours against the quantity of products produced. You will observe that the curve decreases exponentially, showing that when a new production starts, as the number of units produced increases, the labour-hours per unit decreases as operators become more familiar with the task. Learning curves are presented according to the learning rate, for example 75, 80, 85, or 90 percent. Thus, an 80 percent learning means that, as the quantity produced is doubled, the labour-hours per unit decreases by 80 percent.

The mathematical relationship has the exponential form: $T_n = T_1 (n^b)$,

Where

T_n = labour-hours/unit when *n* units are manufactured,

T_1 = labour-hours to produce the first unit;

n = the unit number produced;

b = a constant representing the slope of the curve.

Where the learning rate was found to be 80 percent. In that example, to assemble the first aircraft required 100 labour-hours. Then at 80 percent learning rate, the time to produce the second unit was 80 labour-hours (i.e. 0.8 x 100). The time to produce the fourth unit = 64 labour-hours (i.e. 0. 8 x 80). Table 18.1 gives the progress, while Figure 18.2 earlier referred to, shows the relationship graphically.

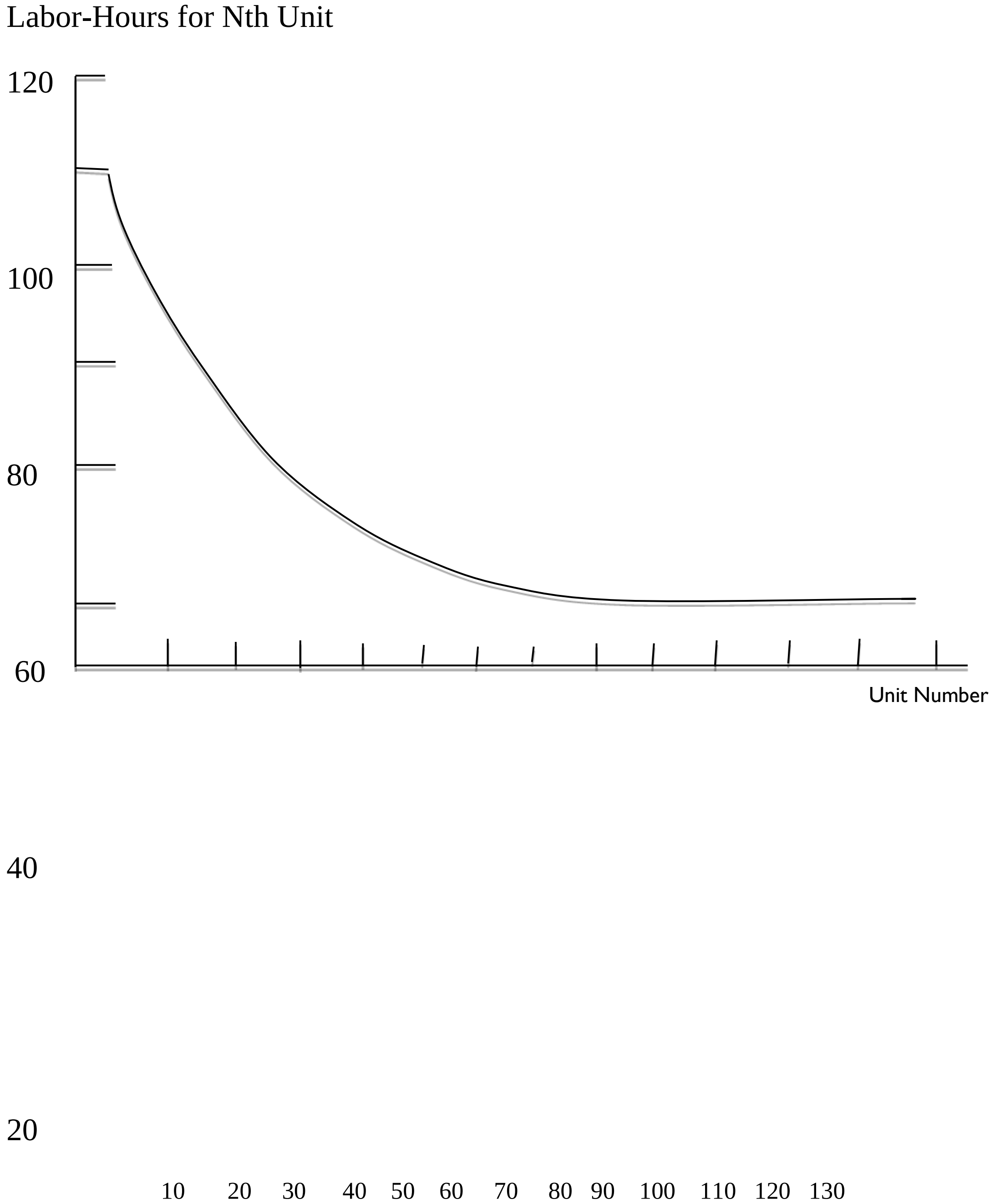


Figure 18.2: Aircraft Assembly 80 Percent Curve

Table 18.1: Relationship between Units produced and Labour-Hour for 80 percent leaning curve

n^{th} Units Produced	Labour-Hours for n^{th} Unit
1	100.0
2	80.0
4	64.0
8	51.2
16	41.0
32	32.8
64	26.2
128	21.0

There are three approaches to learning-curve problems. These are: arithmetic analysis, logarithmic analysis, and learning-curve tables. We shall make attempts to examine each of these.

3.3.1 Arithmetic Analysis

Arithmetic analysis is the simplest approach to learning-curve problems because it is based on this fundamental concept: As the number of units doubles, the labour-hours per unit decline by a constant factor. You are already familiar with this idea. From our previous example, if we know that the learning rate is 80 percent of a particular operation and that the first unit of production took 100 labour-hours, the labour-hours to produce the eight unit is:

n^{th} Units Produced	Labour-Hours for n^{th} Unit
1	100.0
2	80.0
4	64.0
8	51.2

Carefully observe that as long as we wish to find the labour-hours required to produce n units, and n just happens to be a number that is one of the doubled values, then this arithmetic approach works. Would this approach be useful if we want to find the labour-hours required to produce the seventh unit? This is where the arithmetic analysis breaks down: it does not let us address such odd cases with precision. The logarithmic analysis tackles such problems.

3.3.2 Logarithmic Analysis

In Logarithmic analysis, this relationship allows us to compare T_n which is the labour hours required to produce the nth unit:

$T_n = T_I (n^b)$ and $b = \frac{\log r}{\text{Log } 2}$

Where T_I = labour-hours to produce the first unit;

b = slope or me learning curve; ana

r = learning rate percentage

The values of b are found in Table 2 below labour-hours to produce the first unit;

Table 18.2: Learning-curve values of b

Learning rate	b
70%	-0.515
75%	-0.415
80%	-0.322
85%	-0.234
90%	-0.152

It is also possible to compute the values of b manually. This is by making use of the formular for b:

$$b = \frac{\log r}{\log 2}$$

Where r = learning rate percentage

For example, for an 80 percent learning rate, r = 0.80, hence the value of b is:

b = log r = log 0.80 = -0.2231

log 2 log 2 +0.6931

$$b = \frac{\log r}{\log 2} = \frac{\log 0.80}{\log 2} = \frac{-0.2231}{+0.6931}$$

:. b = -0.3219

The negative slope indicates that the time decreases as the number of units increases.
Example

If we know that the learning rate for a particular operation is 80 percent, and that the first unit of production took 100 labour-hours, the labour-hours required to produce the seventh unit is:

$T_n = T_1(n^b)$

$T_7 = 100\ (7^{-{}^{\circ}322}) = 53.4$ labour-hours

We can also calculate the cumulative average number of hours per unit for the first n units with the help of Table 18.3. The table contains conversion factors that, when multiplied by the direct labour-hours for the first unit, yield the average time per unit for selected cumulative production quantities.

Table 18.3:Conversion Factors for the Cumulative Average Number of Direct Labor Hours per Unit

N		N		N		N		n		n	
1	1.00000	19	0.53178	37	0.43976	1	1.00000	19	0.73545	37	0.67091
2	0.90000	20	0.52425	38	0.43634	2	0.95000	20	0.73039	38	0.66839
3	0.83403	21	0.51715	39	0.43304	3	0.91540	21	0.72559	39	0.66595
4	0.78553	22	0.51045	40	0.42984	4	0.88905	22	0.72102	40	0.66357
5	0.74755	23	0.50410	64	0.37382	5	0.86784	23	0.71666	64	0.62043
6	0.71657	24	0.49808	128	0.30269	6	0.85013	24	0.71251	128	0.56069
7	0.69056	25	0.49234	256	0.24405	7	0.83496	25	0.70853	256	0.50586
8	0.66824	26	0.48688	512	0.19622	8	0.82172	26	0.70472	512	0.45594
9	0.64876	27	0.48167	600	0.18661	9	0.80998	27	0.70106	600	0.44519
10	0.63154	28	0.47668	700	0.17771	10	0.79945	28	0.69754	700	0.43496
11	0.61613	29	0.47191	800	0.17034	11	0.78991	29	0.69416	800	0.42629
12	0.60224	30	0.46733	900	0.16408	12	0.78120	30	0.69090	900	0.41878
13	0.58960	31	0.46293	1000	0.15867	13	0.77320	31	0.68775	1000	0.1217
14	0.57802	32	0.45871	1200	0.14972	14	0.76580	32	0.68471	1200	0.40097
15	0.56737	33	0.45464	1400	0.14254	15	0.75891	33	0.68177	1400	0.39173
16	0.55751	34	0.45072	1600	0.13660	16	0.75249	34	0.67893	1600	0.38390
17	0.54834	35	0.44694	1800	0.13155	17	0.74646	35	0.67617	1800	0.37711
18	0.53979	36	0.44329	2000	0.12720	18	0.74080	36	0.67350	2000	0.37114

Example

A manufacturer of ships needs 50,000 labour-hours to produce the first unit. Based on past experience in the ship-building industry, you know that the rate of learning is 80 percent.

(a) Use the logarithmic model to estimate the direct labour required for the 40th ship and the cumulative average number of labour hours per unit for the first 40 units.

(b) Draw a learning curve for this situation

Solution

(i) The estimated number of direct labour-hours required to produce the 40th unit is: T_{40} = 50,000 $(40)^{10'0 .8/log 2)}$

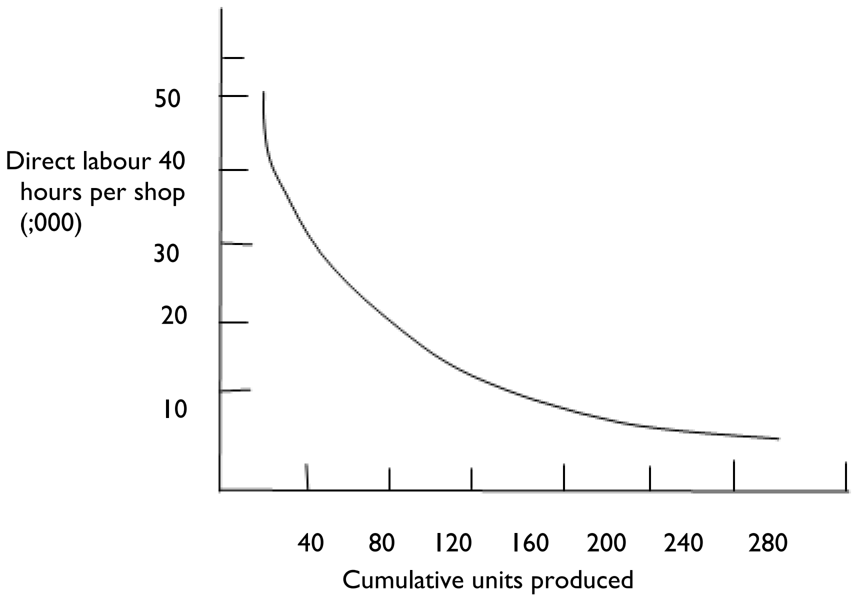
= 50,000 $(40)^{-0.32}$ = 50,000 (0.30488)

= 15,244 hours

i) We calculate the cumulative average number of direct labour-hours per unit for the first 40 units with the help of Table 18.3. For a cumulative production of 40 units and an 80 percent learning rate, the factor is 0.42984. Therefore, the cumulative average direct labour hour per unit is:

50,000 (0.42984) = 21,492 labour-hours

(b) Plot the first point at (1, 50,000). The second unit's labour time is 80 percent of the first, so you need to multiply 50,000 by 0.80, which should give 40,000 labour-hours. Then use to plot the second point at (2, 40,000). The fourth is 80 percent of the second, so multiply 40,000 by 0.80 to obtain 32,000 labour hours. Plot the third point at (4, 32,000). The result is shown in Figure 18.3.



3.3.3 Learning-Curve Tables

The third approach to learning-curve problems is to use a 'learning factor' obtained from a table containing learning curve coefficients. The table shows two things: One is a unit value of each of the outputs listed - this enables us to easily determine how long any unit will take to produce. The second is a cumulative value, which enables us to complete any given number of repetitions. The computation for both is a relatively simple operation. It just entails multiplying the table value by the time required for the first unit. Table 18.4 contains the learning curve coefficient.

Example 1

Alexander Airlines is negotiating a contract for the production of 20 small aircraft. The initial jet requires the equivalent of 400 days of direct labour. Estimate the expected number of days of direct labour for:

(a) The 20th jet

(b) All 20 jets

(c) The average time for 20 jets. Solution

From Table 18.4 n = 20 and an 80 percent learning percentage, the following factors are extracted:

Unit time = 0.3 81

Total time = 10.485

Solution

(a) Expected time for 20th jet: 400 (0.381) = 152.4 labour days

(b) Expected total time for all 20: 400 (10.485) = 4,194 labour days.

(c) Average time for 20: 4,194 20 = 209.7

3.3.3.1 Using the Table to Obtain an Estimate of the Initial Time

Table	18.4: Learning –Curve Coefficients				85%		90%	
Unit No.	Unit Time	Total Time	Unit Time	Total Time	Unit Time	Total Time	Unit Time	Total Time
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	.750	1.750	.800	1.800	.850	1.850	.900	1.900
3	.634	2.384	.702	2.502	.773	2.623	.846	2.746
4	.562	2.946	.642	3.142	.723	3.345	.810	3.556
5	.513	3.459	.596	3.738	.686	4.031	.783	4.339
6	.475	3.934	.562	4.229	.657	4.688	.762	5.101
7	.446	4.380	.534	4.834	.634	5.322	.744	5.845
8	.422	4.802	.512	5.346	.614	5.936	.729	6.574
9	.402	5.204	.493	5.839	.597	6.533	.716	7.290
10	.385	5.589	.477	6.315	.583	7.116	.705	7.994

11	.370	5.958	.462	6.777	.570	7.686	.695	8.689
12	.357	6.315	.449	7.227	.558	8.244	.685	6.374
13	.345	6.660	.438	7.665	.548	8.792	.677	10.05
14	.334	6.994	.428	8.092	.539	9.331	.670	10.72
15	.325	7.319	.418	8.511	.530	9.861	.663	11.38
16	.316	7.635	.410	8.920	.522	10.38	.656	12.04
17	.309	7.944	.402	9.322	.515	10.90	.650	12.69
18	.301	8.255	.394	9.716	.508	11.41	.644	13.33
19	.295	8.540	.387	10.10	.501	11.91	.639	13.97
20	.288	8.828	.381	10.49	.495	12.40	.634	14.61
21	.283	9.111	.375	10.86	.490	12.89	.630	15.24
22	.277	9.388	.370	11.23	.484	13.38	.625	15.86
23	.272	9.660	.364	11.59	.479	13.86	.621	16.48
24	.267	9.928	.359	11.95	.475	14.33	.617	17.10
25	.263	10.19	.355	12.31	.470	14.80	.613	17.71
30	.244	11.45	.335	14.02	.450	17.09	.596	20.73
35	.229	12.62	.318	15.64	.434	19.29	.583	23.67
40	.216	13.72	.305	17.19	.421	21.43	.571	26.54
45	.206	14.77	.294	18.68	.410	23.50	.561	29.37
50	.197	15.78	.284	20.12	.400	25.51	.552	32.14
60	.183	71.67	.268	22.89	.383	29.41	.537	37.57
70	.172	19.43	.255	25.47	.369	33.17	.524	42.87
80	.162	21.09	.244	27.96	.358	36.80	.514	48.05
90	.155	22.67	.235	30.35	.348	40.32	.505	53.14
100	.148	24.18	.227	32.65	.340	43.75	.497	58.14
120	.137	27.02	.214	37.05	.326	50.39	.483	67.93
140	.129	29.67	.204	41.22	.314	56.78	.472	77.46
160	.122	32.17	.195	45.20	.304	62.95	.462	86.80
180	.116	34.54	.188	49.03	.296	68.95	.454	95.96
200	.111	36.80	.182	52.72	.289	74.79	.447	105.0
250	.101	42.08	.169	61.47	.274	88.83	.432	126.9
300	.094	46.94	.159	69.66	.263	102.2	.420	148.2
350	.088	51.48	.152	77.43	.253	115.1	.411	169.0
400	.083	55.75	.145	84.85	.245	127.6	.402	189.3
450	.079	59.80	.140	91.97	.239	139.7	.395	209.2
500	.076	63.68	.135	98.85	.233	151.5	.389	228.8
600	.070	70.97	.128	112.0	.223	174.2	.378	267.1
700	.066	77.77	.121	124.4	.215	196.1	.369	304.5
800	.062	84.18	.116	136.3	.209	217.3	.362	341.0
900	.059	90.26	.112	147.7	.203	237.9	.356	376.9
1,000	.057	96.07	.108	158.7	.198	257.9	.350	412.2
1,200	.053	107.0	.102	179.7	.190	296.6	.340	481.2
1,400	.050	117.2	.097	199.6	.183	333.9	.333	548.4
1,600	.047	126.8	.093	218.6	.177	369.9	.326	614.2
1,800	.045	135.9	.090	236.8	.173	404.9	.320	678.8
2,000	.043	144.7	.087	254.4	.168	438.9	.315	742.3
2,500	.039	165.0	.081	296.1	.160	520.8	.304	897.0
3,000	.036	183.7	.076	335.2	.153	598.9	.296	1.047

The use of Table 18.4 requires a time for the first unit. For instance, if the completion time of the first unit is not available, or if the manager believes the completion time for some later unit is more reliable, the table can be used to obtain an estimate of the initial time, and that value can be used in conjunction with the table.

Example

The manger in our immediate past example believes that some unused problems were encountered in producing the first jet, and would like to revise that estimate based on a completion time of 276 days for the third jet.

Solution

From Table 18.4, with n = 3 and an 80 percent learning percentage a coefficient of 0.702 is obtained. Divide the actual time for unit 3 by the table value to obtain the revised estimate for unit I's time:

276 days   0.702 = 393.2 labour days.

3.4 Uses and Applications of Learning Curves

We now know that as production personnel gain experience with a new product/service or operation, the labour-hours per unit fall. Consequently, labour standards are expected to decline on many products and operations, and cost standards, budgets, production, scheduling, staffing plans, and prices are necessarily affected.

In job shops and custom service operations, the learning-curve theory has been found to be important due to the following factors:

(a) Products and services tend to be custom designs that require workers to start near the beginning of small batches

(b) Batches tend to be small; thus labour-hours per unit improves dramatically from the first to the last unit

(c) Product/service designs tend to be complex; thus labour -hours per unit improve quickly. You should note that the application of learning curves to mass production and standard service operations is less significant because entirely new products or services are rare, and long production runs and simplified tasks combine to cause labour-hours per unit to improve only slightly.

Staff specialists have been found to routinely use learning-curve theory to develop labour cost for new products and services. This use allows companies to prepare cost estimates and product prices for bidding purposes.

The learning-curve approach has certain limitations:

(i) It maybe impossible either to develop precise labour-hour estimates for the first unit, or to determine the appropriate learning rate. Large unique projects often exhibit both at these difficulties.

(ii) Different workers have different learning rates. In a pure sense therefore, learning theory applies only to individual workers, but little difficulty is encountered in applying learning curves to groups of workers by applying an average learning rate.

(iii) Few products are completely unique. Workers usually will trained in the completion of tasks within their skill classifications. Past performance on related tasks therefore results in latent learning that is transferred to new products and services.

Self-Assessment Exercise

1. An assembly operation has a 90 percent learning curve. The line has just begun with on a new item; the initial unit requires 28 hours. Estimate the time that will be needed to complete:

a. The first 5 units

b. Units 20 through 25

2. A manager wants to determine an appropriate learning rate for a new type of work his firm will undertake. He has obtained completion times for the initial six repetitions of a job of this type:

Unit	Completion Time (hours)
1	15.9
2	12.0
3	10.1
4	9.,1
5	8.4
6	7.5

What learning rater is appropriate?

3. The manager of a custom manufacturer has just received a production schedule for an order for 30 large turbines. Over the next five months, the company is to produce 2, 3, 5, 8, and 12 large turbines, respectively. The first unit took 30,000 direct labour hours, and experience on past projects indicates that a 90 percent learning curve is appropriate; therefore the second unit will require only 27,000 hours. Each employee works an average of 150 hours per month. Estimate the total number of full-time employees needed each month for the next five months.

4.0 Conclusion

A basic consideration in the design of work systems relates to the fact that learning is usually present when humans are involved. Consequently, it can be highly desirable to be able to predict how learning will affect task times and costs. You have learned in this unit that the time required to perform a task decreases with increasing repetitions. This is what the learning curves try to summarise.

5.0 Summary

This unit has widened your knowledge to the extent that you can explain the concept of a learning curve, and how volume is related to unit costs. You have also learned how to develop a learning curve by making use of arithmetic and logarithmic analyses. In addition you have been able to demonstrate how to use the learning curve table, as well as use the concept of the learning curves for managerial decision making.

6.0 Self-Assessment Exercise

Company A has just been given the following production schedule for model XT cars. The model is considerably different from any others the company has produced. Historically, the company's learning rate has been 80 percent on large projects. The first unit took 1000 hours to produce.

Month	Units	Cumulative Units
1	3	3
2	7	10
3	10	20
4	12	32
5	4	36
6	2	38

(a) Estimate how many hours would be required to complete the 38th unit.

(b) If the budget only provides for a maximum of 30 direct labour employees in any month and a total of 15,000 direct labour hours for the entire schedule, will the budget be adequate?. Assume that each direct labour employee is productive for 150 work hours each month.

7.0 References/Further Reading

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Unit 4 Total Quality Management

1.0 Introduction

The challenge for business today is to produce quality products or services efficiently. A company that meets this challenge can use quality as a competitive weapon. This unit explores the competitive implications of quality, focusing on the philosophy of total quality management which is an aspect of the topic of quality.

Total quality management (TQM) stresses three principles: customer satisfaction, employee involvement, and continuous improvements in quality. TQM also involves benchmarking, product and services design, process design, purchasing, and problem-solving.

For most companies, superior product quality is at the core of their business strategy. For these companies, attaining near-perfect product quality is seen as the principal means of capturing market share in global competition. The prominence of product quality in business strategy for many firms has come from the painful knowledge that one may lose business to lower-priced products, but one wins it back with superior product quality. Achieving superior product quality within a business requires a long-term process of changing the fundamental culture of the organization.

2.0 Objectives

At the end of this unit, you should be able to:

- define quality from the customer's perspective.
- describe the principles of a TQM program and how the elements fit together to make improvements in quality and productivity
- identify
- discuss how TQM programs improve quality through benchmarking, product and service design, quality function deployment, and quality conscious purchasing
- distinguish among the various tools for improving quality and explain how each should be used
- discuss the nature and benefits of NAFDAC and international standards for quality programs and environmental management programs.

3.0 Main Content

3.1 Quality: A Management Philosophy

Starting in the 1970s, Japanese manufacturers, with the help of American consultants such as W. Edwards Deming and Joseph M. Juran, began making quality a competitive priority. Deming's philosophy was that quality is the responsibility of management, not the workers, and the management must foster an environment for detecting and solving quality problems.

Juran believed that continuous improvement, hands-on management, and training are fundamental to achieving excellence in quality. Foreign competitors with superior goods may dominate the local market with inferior alternatives. A good example is the imported and local rice in Nigeria. Manufacturers need to listen to the customers or lose market share. This realization has helped the Japanese manufacturers over the years. The global economy of the 1990s and beyond dictates that companies provide the customer with an ever widening array of products and services having high level of quality.

3.1.1 Customer-Driven Definition of Quality

Customers define quality in various ways. Generally, quality may be defined as meeting or exceeding the expectations of the customer. However, quality has multiple dimensions in the mind of the consumer, and one or more of the following definitions may apply at any one time.

(a) Conformance to specifications

Customers expect the products or services they buy to meet or exceed certain advertised levels of performance. When Nestle advertises milo as "the drink of future champions, the expectation of the customers is high as to the pleasure they will derive from taking milo. They will be expecting to gain energy, strength or vitality. If they derive all these or even more, then milo conforms to specification.

(b) Value

Another way customers define quality is through value, or how well the product or service, serves its intended purpose at a price customers are willing to pay. How much value a product or service has in the mind of the customers depends on the customer's expectations before purchasing it. For example if you spent N 10 to buy an Eleganza ball point pen and it served you well for 3 weeks, you might feel that the purchase was worth the price. Your expectations for the product were met or exceeded. However, if the pen lasted only 3 days, you might be disappointed and feel that the value wasn't there.

(c)Fitness for use

In assessing fitness for use, or how well the product or service perform its intended purpose, the customer may consider the mechanical features of a product or the convenience of a service. Other aspects of fitness for use include appearance, style, durability, reliability, craftsmanship and serviceability. For example, a retailer of frozen fish may find a deep freezer fit for product storage while a wholesaler will need a cold room.

(d) Support

Often the product or service support provided by the company is as important to customers as the quality of the product or service itself. Customers get upset with a company if financial statements are incorrect, responses to warranty claims are delayed, or advertising is misleading. Good product support can reduce the consequences of quality failures in other areas. You may decide to buy your upholstery from a furniture worker who agrees to transport it to your apartment.

(e) Psychological Impression

People often evaluate the quality of a product or service on the basis of psychological impressions: atmosphere, image, or aesthetics. The appearance and actions of the service provider are very important. Nicely dressed, courteous, friendly, and sympathetic employees can affect the customer's perception of service quality. For example, rumpled, discourteous, or grumpy waiters can undermine a restaurant's best efforts to provide high-quality service.

3.1.2 Quality as a Competitive Weapon

Attaining quality in all areas of a business is a difficult task because perceptions of quality by customers change over time. For instance, changes in life-styles and economic conditions have drastically altered customer perceptions of automobile quality. During austerity, most Nigerians go for second-hand (Tokunbo) cars especially models with economic fuel consumption. But as the economy improves, more people buy better cars.

A business's success depends on the accuracy of its prediction of consumer's expectation and the ability to bridge the gap between those expectations and operating capabilities. Consumers are now quality-minded than in the past. Research findings indicate that a high quality product has a better chance of gaining market share than does a low-quality product. Most modern firms believe that their total quality management (TQM) programmes are highly successful in retaining customers and building satisfaction. More over, perception of a product as being of high quality by customers gives it better chance over those considered to be of low-quality even if the level of their quality is the same.

Good quality can pay off in higher profit. High-quality products and services can be priced higher than comparable lower quality ones and yield a greater return for the same sales naira. Poor quality erodes the firm's ability to compete in the market place and increase the costs of producing its products or service.

3.2 Employee involvement

One important component of TQM is employee involvement. A complete programme in employee involvement includes changing organizational culture, fostering individual development through training, establishing awards and incentives, and encouraging team work.

3.2.1Cultural Change

The challenge of quality management is to instill an awareness of the importance of quality in all employees and to motivate them to improve product quality. With TQM, everyone is expected to contribute to the overall improvement of quality - from the administrator who finds cost- saving measures to the salesperson that learns of a new customer need, to the engineer who designs a product.

Customers can either be internal or external. External customers are the people or firms who buy the product or service. Thus the entire firm must do its best to satisfy them. It is often difficult for employees who are not dealing directly with customers to see their contribution to TQM, but this is not to say that they are less important. Each employee has one or more internal customers - employees in the firm who rely on the output of other employees. For example, a printer who prints a book and passes it on to a binder has the binder as his customer.

The binder will have similar perception of quality as final consumer. All employees have to do a good job of serving their internal customers for ultimate satisfaction of the external customers. The concept of internal customers works, if each internal customer demands only value-added activities of their internal suppliers: that is, activities that the external customer will recognize and pay for. The concept of internal customers applies to all parts of a firm and enhances cross functional coordination.

TQM makes quality control everyone's business where errors are promptly detected and corrected internally before they get to the final consumers. This philosophy is called quality at the source. Firms should try to avoid "inspecting quality into the product" by using inspectors to detect defective product after all operations have been performed. Some firms authorize workers to stop a production line if they spot quality problem.

3.2.2 Individual Development

On the job training can help improve quality. Teaching new work methods to experienced workers or training new employees in current practices can increase productivity and reduce the number of product defects. Some companies train workers to perform related jobs to help them understand how quality problems in their own work can cause problems for other workers. Managers too need to develop new skills in order to teach their subordinates. They may have to embark on "train - the - trainer" programme to acquire skills to train others in quality improvement practices.

3.2.3 Awards and Incentives

The prospect of merit pay and bonuses can give employees some incentive for improving quality. Companies may tie monetary incentives directly to quality improvements.

Non-monetary awards, such as recognition in front of co-workers, also can motivate quality improvements. Some companies periodically select an employee who has demonstrated quality workmanship and give them special recognition e.g. a special dinner, such performance may even be reported in the company newsletter.

3.3 Continuous Improvement

Continuous improvement, based on a Japanese concept called "Kaizen", is the philosophy of continually seeking way to improve operations. It is also applicable to process improvement. Continuous improvement involves identifying benchmarks of excellent practice and instilling a sense of employee ownership in the process. The focus can be on reducing the length of time required to process request for loans at a bank. Continuous improvement can also focus on problems with customers or suppliers. The bases of continuous improvement is that if people involved in a process can identify the needed changes to be made, the process can be improved upon. An organization should not wait until massive problem occurs before acting.

3.3.1 Getting Started with Continuous Improvement

Instilling the philosophy of continuous improvement involves the following processes:

(a) Train employees in the methods of statistical process control (SPC) and other tools for improving quality and performance.

(b) Make SPC methods a normal aspect of daily operations.

(c) Build work teams and employee involvement

(d) Utilize problem-solving tools within the work teams.

(e) Develop a sense of operator ownership in the process.

Note that employee involvement is central to the philosophy of continuous improvement. The last two steps are crucial if the philosophy is to become part of everyday operations. Problem solving addresses the aspects of operations that need improvement. A sense of operator ownership emerges when employees feel as though they own the processes and methods they use and take pride in the quality of the product or service they produce.

3.3.2 Problem-Solving Process

Firms that are actively involved in continuous improvement train their work teams to use the plan-do-check-act cycle of problem solving. The approach is called Deming wheel and it lies in the heart of the continuous improvement philosophy. The steps involved are.

(i) Plan. The team selects a process (activity, method, machine, policy e.t.c.) that needs improvement. The team then documents the selected process, by analyzing data; sets qualitative goals for improvement; and discusses various ways to achieve the goal. After assessing the benefits and costs of the alternatives, the team develops a plan with quantifiable measures for improvement.

(ii) Do. The team implements the plan and monitors progress. Data are collected continuously to measure the improvements in the process. Any further revisions are made as needed.

(iii) Check. The team analyzes the data collected during the do step to find out how closely the results correspond to the goals set in the plan step. If major short comings exist, the team may have to reevaluate the plan or stop the plan or stop the project.

(iv) Act. If the results are successful, the team documents the revised process so that it becomes the standard procedure for all who may use it. The team may then instruct other employees in the use of the revised process.

3.4 The Cost of Poor Quality

Defective and unsatisfactory product may cost a company up to 20 to 30 percent of its gross sales. For instance, a high electric power surge may damage all electrical appliances of a company as low current supply may delay operations. Four major categories of cost are associated with quality management: prevention, appraisal, internal failure, and external failure.

3.4.1Prevention Costs

These are incurred when preventing defects from happening. These include the cost of redesigning the process and product, training of employees and working with suppliers to increase the quality of purchased items. In order to improve quality, firms invest in additional time, efforts, and money.

3.4.2 Appraisal Costs

These are incurred in Assessing the Level of Quality Attained by the Operating System.

This helps to identify quality problems and proffer measures to improve quality, appraisal costs decrease due to quality inspections.

3.4.3 Internal Failure Costs

These result from defects that are discovered during the production of product or service. They fall into two categories: yield losses and rework costs. Yield losses are incurred if a defective item must be scrapped. Rework Costs are incurred if item is rerouted to some previous operation (s) to correct the defect or if the service must be performed again. Additional time spent to correct mistakes lowers productivity of a unit.

3.4.4 External Failure Costs

Arise when a defect is discovered after the customer has received the product or service. For instance, suppose you discover that your dry cleaner has burnt one of your clothes given to him, you may demand that he amends it for you. External failure cost erodes market share of profits. The costs include warranty service and litigation costs. A warranty is a written guarantee that the product will be replaced or repair the defective parts or perform the service to the customer's satisfaction.

Defective products can injure and even kill consumer who purchase them. Thus it is important to prevent them from getting to the final consumer. External failure costs also include litigation cost. These include legal fees, time and effort of employees who appear for the company in court. The cost of litigation is enormous and the negative publicity can be devastating.

3.5 Improving Quality through TQM

Employee involvement and continuous improvement generally improve quality. But, TQM often focuses on benchmarking, product and service design, process design and purchasing.

3.5.1Benchmarking

Benchmarking is a continuous systematic procedure that measures a firm's products, services and processes against those of industry leaders. Companies use the outstanding company in the industry as standard they would like to attain to. Typical measures used in, benchmarking include cost per unit, service per customer, processing time per unit, customer retention rates, revenue per unit, return on investment, and customer satisfaction levels. Benchmarking consists of four basic steps".

(i) Planning - Identifying the product, service or process to be benchmarked and the firms (s) to be used for comparison, determine the measures of performance for analysis, and collect data

(ii) Analysis - Determine the difference between the firm's current performance and that of the benchmark firm (s) and identify the causes of significant gaps.

(iii) Integration - Establishing goals and obtaining the support of managers who must provide the resources for achieving the goals.

(iv) Action - This involves determining the team affected by the changes, developing action plans and assignments, implementing the plan, monitoring progress and watching the level attained on the benchmark.

Benchmarking focuses on setting of quantitative goals for continuous improvement. Comparative benchmarking is based on comparisons with a direct industry competitor. Functional benchmarking compares areas such as administration, customer service and sales operations with those of outstanding firms in an industry. Internal benchmarking involves using an organisational unit with superior performance as the benchmark for other units. All forms of benchmarking are applied when there is a need for continuous improvement.

3.5.2 Product and Service Design

Because design changes often require changes in methods, materials, or specifications, they can increase defect rates. Change increases the risk of making mistakes, so stable product and service designs can help reduce internal quality problems. Stable designs may not be possible when a product or service is sold in markets globally. Although changed designs have the potential to increase market share, management must be aware of possible quality problems resulting from changes. A firm may need to change design to remain competitive; it should carefully test new designs and redesign the product with a focus on the market. Higher quality and increased competitiveness are exchanged for added time and cost.

Another dimension of quality related to product design is reliability. Reliability is the probability that the product will be functional when used. Products often consist of a number of components that must be operative for them to perform as expected. Some products can be designed with extra components/subsystems so that if one system component fails another can be activated.

Suppose that a product has subsystems, each with its own reliability measure. The reliability of the product is equal to the product of the reliabilities of all the subsystems, i.e.

$r_s = (r_l)\ (r2) \ldots (r_n)$ .... (i)

Where

r_s = reliability of the complete product.

n = number of subsystems

r_n = reliability of the subsystem n

This measure is based on the assumption that the reliability of each component depends on those of others.

Suppose you have a table fan, and you discover that the reliability of its plug is 0.95, that of the cord 0.90 that of the switch is 0.88 and the coil has 0.70 reliability. The reliabilities are the probabilities that each subsystem will still be operating three years from now. The reliability of the table fan is

R_s=(0.95) (0.90) (0.88) (0.70) = 0.53

The table fan thus has a reliability of 0.53. This is the probability that it will not fail to work when you put it on.

3.5.3 Process Design

Process designs greatly affect product quality. Wema Bank PLC may observe that the average waiting time to pay NEPA bill in all its branches is one hour. It may want to reduce the waiting time to 30 minutes by assigning only one cashier to customer waiting to pay such bills.

The purchase of new and efficient machinery can help to prevent or overcome quality problem. The cost of the machinery is the trade-off for reducing the percentage of defects and their cost.

One of the keys to obtaining high quality is concurrent engineering in which operation's manager work hand in hand with designers in the initial phases of product or service design to ensure that production requirements and process capabilities are synchronized. This results in better quality and shorter development time.

3.5.4 Quality Function Deployment

A key to improving quality is to link the design of products or services to the processes that produce them. Quality Function Deployment (QFD) is a means of translating customer requirements into the appropriate technical requirements for each stage of product or service development and production. This approach seeks answers to the following questions.

(a) Voice of the customer - what do our customers need and want?

(b) Competitive analysis - How well are we doing relative to our competitors, in terms of our customers?

(c) Voice of the engineer - what technical measures relate to our customers' needs?

(d) Correlation - what is the relationship between the Voice of customer and the voice of the engineer?

(e) Technical comparison - How does our product/service perform compared to that of our competitors?

(f) Trade-offs - what are the potential technical trade - offs?

The QFD approach provides a way to set targets and debate their effects on product quality. QFD encourages inter functional communication for the purpose of improving product quality.

3.5.5 Purchasing Considerations

Most firms depend on outside suppliers for some of the materials, services, or equipment used in producing their products and services. Large companies have many of such suppliers, some of which supply them the same material. The quality of these inputs can affect the quality of the firm's work

Both the buyer's approach and specification management are keys to controlling supplier quality. The firm's buyer must emphasize the cost, and speed of delivery of the supplier as well as the quality of the product. The buyer identifies suppliers with high - quality products and arranges to buy from them.

The specifications for the purchased items must be clear and realistic. The buyers initiate process capability studies for important products. This involves trial runs of small product samples to ensure that the quality is as specified and will perform as desired at the given cost. Management needs to allow sufficient time for the purchasing unit and may work closely with other units e.g. engineering to ensure quality control.

3.5.6 Tools for Improving Quality and Performance

The first step in improving quality of an operation is data collection. There are seven tools for organizing and presenting data to identify areas for quality and performance improvement. These are:

Checklists, histograms and bar charts, Pareto charts, scatter diagrams, cause-and-effect diagrams, graphs, and control charts. We discuss six of them here.

(a) Checklists

A checklist is a form used to record the frequency of occurrence of certain product or service characteristics related to quality. The characteristics may be measurable on continuous scale (e.g. weight or time) or on yes-or-no basis

(b) Histograms and Bar chats

A histogram summarizes data measured on a continuous scale, showing the frequency distribution of some quality characteristic. A bar chart is a series of bars representing the frequency of occurrence of data characteristics measured on a yes-or-no basis.

(c) Pareto Charts

When managers discover several quality problems that need to be addressed, they have to decide on which to tackle first. Vilfredo Pareto proposed that most of an "activity" is caused by relatively few of its factors. In a restaurant quality problem, the activity could be customer complaints and the factor could be "discourteous waiter".

Pareto's concept, called the 80-20 rule, is that 80 per cent of the activity is caused by 20 percent of the factors. Thus, by concentrating on the 20 per cent of the factors, managers can attack 80 percent of the quality problem.

A Pareto chart is a bar chart on which the factors are plotted in decreasing order of frequency along the horizontal axis. The chart has two vertical axis, the one on the left showing frequency and the one on the right showing the cumulative percentage of frequency curve, identifies the few vital factors that warrants immediate managerial attention.

(d) Scatter diagram

A scatter diagram is a plot of two variables showing whether they are related or not and can be used to clear doubt about a factor causing one quality problem. Each point on the scatter diagram represents a data observation.

(e) Cause-and-Effect Diagrams

One way to identify a design problem that needs to be corrected is to develop a cause-and - effect diagram that relates a key quality problem to its potential causes. The diagram helps management to trace customer complaints directly to the operations involved.

The cause-and-effect diagram is also known as a fishbone diagram. The main quality problem is labeled as the fish's "head", the major categories of potential causes as structural "bones" and the likely specific causes as "ribs". The diagram below is used to illustrate this.

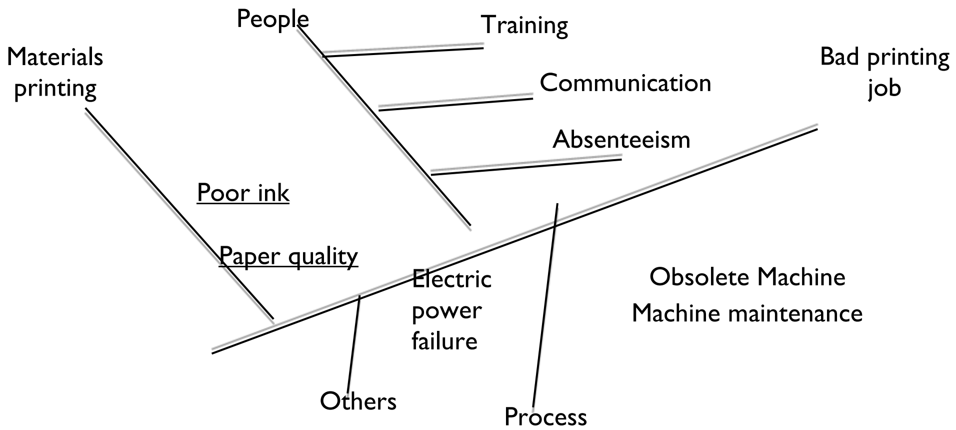

Figure 19.1:

From Figure 19.1, the head or problem is bad printing job. The main causes forming the structural bones are people, material, process and other causes. These all have specific causes.

(f) Graphs

Graphs represent data in a variety of pictorial formats, such as line graphs and pie charts. Line graphs represent data sequentially with data points corrected by line segments to highlight trends in the data. Pie charts represent quality factors as slices of a pie, the size of each slice is in proportion to the number of occurrence of the factor.

3.5.7 Data Snooping

Each of the tools for improving quality may be used independently, but their power is greatest when they are used together. Managers may need to shift data to clarify the issues involved in deducing the causes. This process is called data snooping.

3.6 National and International Quality Standards

3.6.1National Quality Standards

Products and services quality are standardized by various public and private agents in Nigeria. These could be trade unions, professional bodies or government agencies e.g. licencing office. Accountants, Engineers e.t.c. have their professional bodies that maintain standard in their profession. The Nigerian University Commission for instance, maintains standard and quality of university education in Nigeria.

The National Agency for Food and Drug Administration and Control (NAFDAC) is saddled with responsibility of maintaining standard in food and pharmaceutical industry.

3.6.2 International Quality Standard

Companies selling in international markets may have difficulty complying with varying quality documentation standards in countries where they do business. To cope with this problem, the international organization for standardization devised a set of standards called ISO 9000 for companies doing business in the European Union. Also, a new set of standards, ISO14000, were devised for environmental management systems.

(a) The ISO 9000 standards is a set of standards governing documentation of a quality programme. Companies become certified buy proving to a qualified external examiner that they have complied with all the requirements. Companies thus certified are listed in the directory for potential customer to know that such companies can own-up their claims on their products. This tells nothing on the actual quality of the product. The ISO 9000 consists of 5 documents: ISO 9000 - 9004

(b) ISO 14000 - An Environmental management system.

The ISO 14000 standards require participating companies to keep track of their raw materials use and their generation, treatment, and disposal of hazardous wastes. The standard is to ensure improvement in environmental performance. ISO 14000 is a series of 5 standards covering the following areas.

- Environmental management system
- Environmental performance evaluation
- Environmental labeling
- Life-cycle assessments

4.0 Conclusion

Total quality management is a big challenge for all modern businesses. Products and services will meet customers' expectations for satisfaction if they have good quality for their money value. Good quality is not a thing to be inspected for in a product after final production but a thing that is built into the product from the beginning of the production process. Everyone in the firm-management, employees and all the units need to be carried along in quality management. Contacts have to be maintained with customers too as their perception of quality changes over time.

5.0 Summary

Total quality management is built on three principles: customer-driven focus, employee involvement, and continuous quality improvement. Quality means a variety of things to customers. A customer may make a qualitative judgment about whether a product or service meets specified design characteristic. Another may make qualitative judgment about value, fitness for the customer's intended use, product or service support, and aesthetic reasons. One TQM responsibility of marketing is to listen to customers and report their changing perceptions of quality.

Quality can be used as a competitive weapon. World-class competition requires businesses to produce quality products or services efficiently Responsibility for quality is shared by all employees in the organizations. Managers too need to develop skills for teaching their subordinates.

Continuous improvement involves identifying benchmarks of excellent practices and instilling a sense of ownership in employees so that they will continually identify product, services or process that need improvement. Quality management is important because of its impact on market share, price, and profits and because of the costs of poor quality. The four categories of costs associated with quality management are prevention, appraisal, internal failure, and external failure. Benchmarking is a comparative measure used to establish goals for continuous improvement. Forms of benchmarking are competitive, functional and internal concurrent engineering improves the match between product design and production process capabilities. Quality improvement requires close cooperation among functions (design, operations, marketing, purchasing etc.)

Keys to controlling supplier quality are buyer's approach and specification management. The buyer must consider quality, delivery, and cost.

Approaches to organizing and presenting quality improvement data include check lists, scatter diagrams, cause-and-effect diagrams, Pareto charts, bar charts, graph and control charts.

Quality management in Nigeria is done by various public and private agencies. NAFDAC monitors quality in the food and drugs industry.

Two sets of standard, governing the documentation of quality programmes at the global level are ISO 9000 and ISO 14000.

6.0 Self-Assessment Exercise

A semiconductor has 3 components in series. Component 1 has a reliability of 0.96, Component 2, 0.98 and component 3, 0.97 what is the reliability of the semiconductor

7.0 References/Further Reading

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Unit 5 Maintenance and Reliability

1.0 Introduction

This unit is on maintenance, which encompasses all these activities that relate to keeping facilities and equipment in good working order and makes necessary repairs when break-downs occur, so that the system can perform as intended. The general objectives for the unit are set below.

2.0 Objectives

At the end of this unit, you should be able to:

- explain the importance of maintenance in production systems.
- describe the range of maintenance activities
- describe and differentiate between reactive and proactive approaches to maintenance
- state how the Pareto phenomenon pertains to maintenance decisions.

3.0 Main Content

3.1 An Overview of Maintenance

Maintaining the production capability of an organization is an important function in any production system. It is through this that production equipment are adjusted, repaired and kept in good operating conditions. The reasons for keeping equipment and facilities in perfect operating condition are not only to avoid interruption to production, but also to keep production cost low, keep product quantity high, maintain safe working conditions, and avoid late on late shipments to customers.

When equipment malfunctions in both manufacturing and service industries, the consequences have a direct impact on:

(i) **Production capacity:** Naturally, equipment sidelined by breakdown cannot produce. This way, the capacity of the system is reduced.

(ii) **Production costs:** Since machines are not functioning, workers too would be made idle. This situation cause labour costs per unit to increase. Apart from this, when machine malfunction causes scrap products to be produced, unit labour and material costs increase. Furthermore, maintenance department budgets include such costs as the costs of providing repair facilities, repair crew, preventive maintenance inspections, standby machines, and spare parts.

(iii) **Product and service quality:** Usually, poorly maintained equipment produces low - quality products.

(iv) Employee or customer safety: Worn-out equipment is most likely to fail at any moment while in operation. These failures can cause injuries to workers, as well as to customers (especially in the services sector)

(v) Customers satisfaction: Whenever production equipment breaks down, the initial after math is that products cannot be produced according to the master production schedules. In essence, customers may not receive products when promised.

For better maintenance management, maintenance department are usually developed within organizations. A maintenance manager is usually a plant engineer, who reports to either a plant manager or a manufacturing manager. Generally, the organizational level of the department depends on the importance of maintenance to a particular organization.

Maintenance activities are often organized into two categories:

(1) buildings and grounds, and

(2) equipment maintenance. Buildings and grounds is responsible for the appearance and functioning of buildings, parking lots, Lawns, fences, etc. The buildings and grounds workers include electricians, welders, pipe fitters, steamfitters, painters, glaziers, carpenters, janitors, and grounds keepers.

The equipment maintenance group is responsible for maintaining machinery and equipment in good working condition, and making all necessary repairs. This group can include such workers as machineries, mechanics, welders, oilers, electricians, instrument calibrators, and electronic technicians.

The degree of technology of the production processes, the amount of investment in plant and equipments, the age of the buildings and equipment, and other factors will affect how maintenance departments are organized, the required workers skills, and the overall mission of maintenance departments.

3.2 Approaches to Maintenance

Decision makers have two basic options with respect to maintenance. The first is option reactive and this is to deal with breakdowns or other problems when they occur. This is commonly referred to as breakdown maintenance (B M). The second option is proactive, the purpose of which is to reduce breakdowns through a programme of lubrication, adjustment, cleaning, inspecting, and replacement of worn parts. This is generally knows as preventive maintenance (PM).

Usually a trade-off is made between these two basic options that will minimize their combined cost. For instance, with no preventive maintenance, breakdown and repair costs would be tremendous. In addition, hidden costs, such as cost production and the loss of wages while the equipment is not in service must be considered. Cost injury and damage to other equipment and facilities or to other units in production must also be taken into consideration.

However, beyond a certain point, the cost of preventive maintenance activities exceeds the benefit. The best approach really, is to seek a balance between preventive maintenance costs and breakdown maintenance costs. This concept is illustrated in Figure 20.1

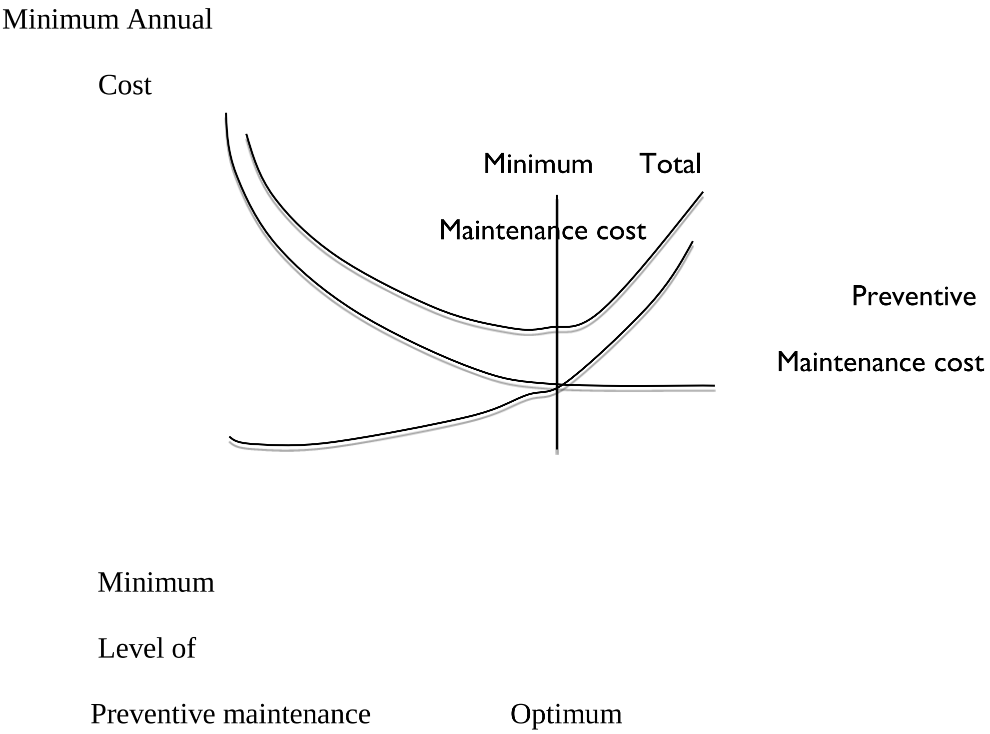

Figure 20.1:

Amount of Preventive Maintenance

As figure 20.1 shows, some minimum amount of PM is necessary to provide the mini mal amount of lubrication and adjustment to avoid a complete and imminent collapse of the production system. At this minimal level of PM, the cost of breakdowns, interruption to production, and repairs is so high that total production, and repair is so high that the production cost is beyond practical limits. This is mainly a remedial policy, i.e., fix the machines only when they breakdown or will not operate any longer. As the PM effort is increased, breakdown and repair cost is reduced. Note that the total maintenance cost is the sum of the PM and the breakdown and repair costs. Also observe that at some point, for each piece of equipment, addition spending for PM is uneconomical because PM costs rise faster than breakdown and repair costs fall. Conceptually, operations managers seek to find the optimal level of PM where total maintenance costs are at a minimum both for each piece of equipment and the entire production system. Let us examine both the PM and BM into some detail.

3.2.1 Preventive Maintenance (PM)

As you must be aware by now, the goal of PM is to reduce the incidence of breakdowns or failures in the plant or equipment in order to avoid the associated costs. These can include loss of output, idle workers, schedule reduction; damage to other equipment, products, or facilities, and repairs, which may involve maintaining inventories of spare parts, repair tools and equipment, and repair specialists.

In particular, PM can be an important factor in achieving operation's strategies. For example, a PM program can be essential to the success of a product-focused positioning strategy. In product-focused positioning strategies, standardized product designs are produced along production lines where these are little, if any in-process inventories between adjacent operations. Hence, if a machine breakdown at one operation, all other downstream operations will soon run out of parts of work on. Therefore, an extensive PM programme in such system will reduce the frequency and severity of machine breakdowns.

PM programmes are similarly essential in automated factories, where systems of automated machines operate continuously without the need for production workers (i.e. workless factories). In such an environment, a large number of maintenance workers would be needed to keep the machines adjusted, lubricated, and in good operating condition.

Very often, PM is periodic, and it can be programmed according to the availability of maintenance personnel as well as to avoid interference with operating schedules. PM is generally programmed using some combination of the following three options.

(i) The result of planned inspections that reveal a need for maintenance

(ii) According to the calendar (passage of time)

(iii) After a pre-determined number of operating hours.

Normally, PM is performed just prior to a breakdown or failure because this will result in the longest possible use of equipment of facilities without a breakdown. Predictive maintenance is an attempt to determine when to perform PM activities. It is generally based on historical records and analysis of technical data to predict when a piece of equipment or part is about to fail. The effectiveness of PM often depends on how good the predictions of failures are. A good PM effort relies on complete records for each piece of equipment. Such records must include information like date of installation, operating hours, dates and types of maintenance and dates and types of repairs.

A new concept, known as Total Preventive Maintenance (TPM) is being practiced in Japan. Companies operating TPM usually have their workers Perform PM on the machines they operate, rather than use separate maintenance personnel for that task. The TPM is consistent with Just-In-Time (JIT) systems and lean production, where employees are given greater responsibility for quality, productivity, and the general functioning of the system.

3.2.2 Breakdown Maintenance (BM)

Though the risk of a breakdown can be drastically reduced on by an effective PM programme, occasional breakdowns may still occur. Actually, firms with good preventive practices have some need for breakdown programmes. It is obvious that organisations that rely less on PM have an even greater need for effective ways of dealing with breakdowns.

Very much unlike PM, breakdowns cannot be scheduled. Rather they must be dealt with on an irregular basis (i.e. as they occur). The following approaches are being used to deal with breakdowns:

(i) Standby or backup equipment that can be quickly pressed into service

(ii) Inventories of spare parts that can be installed as needed, thereby avoiding lead times involved in ordering parts, and buffer inventories, so that other equipment will be less likely to be affected by short-term downtime of a particular piece of equipment.

(iii) Operators who are able to perform at least minor repairs on their equipment.

(iv) Repair people who are well trained and readily available to diagnose and correct problems with equipment.

The extent to which any organisation pursues any or all of these approaches depends on how important a particular piece of equipment is to the overall production system. At one extreme is the equipment that is the focal point of a system (e.g. vital operating parts of a car, such as brakes, transmission, ignition and engines or printing presses for a publishing house). At the other extreme is the equipment that is rarely used since it does not perform any important function in the system, and equipment for which substitutes are readily available. What is the implication of this? Usually, breakdown programmes are most effective when they take into account, the degree of importance a piece of equipment has in the production system, as well as the ability of the system to do without it for a period of time. For these types of situations, the Pareto phenomenon exists: A relatively few pieces of equipment will be extremely important to the functioning of the system, thereby justifying considerable effort and/or expense; some will require moderate effort or expense; some will require moderate effort or expense and many will justify little effort or expense.

3.3 Replacement Decisions

These are situations when breakdowns become frequent and/or costly. The manager is thus faced with a trade-off decision in which costs are important consideration. What is the cost of replacement compared with the cost of continued maintenance? At times, a question like this is difficult to resolve, most especially if future breakdowns cannot be readily predicted. The manager may thus, need to examine historical records in order to project future experience.

Another important factor is technological change. For instance, newer equipment may have some features that favour replacement over either preventive or breakdown maintenance. At the same time, the removal of old equipment and the installation of new equipment may cause disruptions to the system, which may actually be greater than the disruptions caused by breakdowns. In addition, employees may have to be trained to operate the new equipment. Finally, forecasts of future demand for the use of the present or new equipment must be taken into account.

3.4 Machine Reliability

It is necessary for you to know the concepts of reliability and their relationship to maintenance management. Machine reliability is the likelihood of a machine breaking down, malfunctioning, or needing repairs in a given time period or number of hours of use. If machine reliability can be increased, the incidence of machine breakdowns and the cost of the havoc caused in production by breakdowns can also be reduced.

There are three approaches to improving machine reliability: over-design, design simplification, and redundant components. All these take place by the time a machine is designed. Over design means enhancing a design to avoid a particular type of failure. For instance, if a machine has only a few independent critical interacting parts, then over design may be an effective way of increasing machine reliability.

Design simplification implies a reduction in the number of interacting parts in a machine. Since there are now fever parts that can fail, machine reliability increases when the number of interacting part s is reduced. Redundant components are the building of backup components right into the machine so that if one part fails, its backing is automatically substituted. These three approaches can be sued together or separately to design more reliable machines.

3.5 Secondary Maintenance Responsibilities

As earlier mentioned, all maintenance departments are responsible for the repair of buildings and equipment and for performing certain preventive maintenance inspections, repairs, lubrication, and adjustments.

Additionally, some particular responsibilities have traditionally been added to these departments. For instance, housekeeping, janitorial, window cleaning, ground keeping and painting services are now usually performed by maintenance departments. These activities often embrace all areas of the facility, from restrooms to offices to production departments to warehouses. Within some plants, it is usual to find the area around each production worker's immediate workplace being cleaned by the worker, while the appearance and cleanliness of all other areas are the responsibility of the maintenance department.

Again, in some organisations, additional activities such as new construction, remodeling, safety equipment maintenance, loss prevention, security, public hazard control. Waste disposal and recycling and pollution control responsibilities have been assigned to their maintenance departments.

3.6 Current Trends in Maintenance Management

There is no doubt that production machinery today is far more complex than it was some years ago. For instance, computerised controls, robotic (especially in developed countries) new technology in metallurgy, more sophisticated electronic controls, new methods in lubrication technology and other developments have resulted in the way complex machines are maintained.

Consequently, special training programmes are being mounted to give maintenance workers the skills necessary to service and repair today's specialised equipment. In addition, subcontracting service firms have evolved to supply specialised maintenance services. It is now common to see computers, automobiles, office machines, and other equipment and facilities being serviced by outside subcontracting firms. In particular, their specialised training and fee structure, which is usually based on an as needed basis, combine to offer competent service at reasonable cost.

Furthermore, other technologies that reduce the cost of maintenance while improving the performance of production machines are now available. An example here is the network of computerized temperature - sensing probes connected to all key bearings in a machine system. When bearings being to fail, they overheat and vibrate, thus causing these sensing systems to indicate that a failure is imminent. Consequently, the massive damage to machines that could happen when bearings fail can therefore be avoided.

Another modern trend is the application of computers to maintenance management. There are at least five general areas in maintenance that commonly use computer assistance. These are:

(i) Scheduling maintenance projects

(ii) Maintenance cost reports by production department, cost category and other classifications

(iii) Inventory status reports for maintenance parts and supplies

(iv) Parts failure data, and

(v) Operations analysis studies, which may include computer simulation, waiting lines (queuing theory), and other analytical programmes.

In spite of the fact that computers, robots, and high-tech machinery are important concerns in maintenance management today, people concerns may actually be at the heart of better maintenance. Hence, one important trend is the involvement of production workers in repairing their own machines and performing PM on their own machines. In this regard, widening the scope of workers' jobs to include maintenance of their machines, would not only improve maintenance, but may actually result in numerous side benefits.

From this discussion, it is very clear that maintenance today in production and operations management (POM) means more than simply maintaining the machines of production. Since POM has broadened its perspectives from minimizing short range costs to other, long-range performance measures such as customer service, return on investment, product quality, and providing for workers' needs, maintenance too, has broadened its own perspectives. Hence, maintenance in the present day means that the prompt supply of quality products and services is what is maintained, not merely machines.

4.0 Conclusion

You have learned in this unit, the importance of keeping production equipment adjusted, repaired, and in good operating condition. You also learned the direct impacts of equipment malfunctioning on both manufacturing and service industries. You were again thought that maintenance today means more than simply maintaining the machines of production. In addition, prompt supply of quality products and services is also maintained.

5.0 Summary

Maintaining the productive capability of an organisation is an important function. Maintenance includes all of the activities related to keeping facilities and equipment in good operating order and maintaining the appearance of buildings and grounds.

Self-Assessment Exercise

1. List the costs associated with equipment breakdown

2. What are three different ways preventive maintenance is scheduled?

3. Explain the term predictive maintenance and the importance of good records.

6.0 Self-Assessment Exercise

1. What are the current trends in maintenance management?

2. Discuss the approaches being used to deal with breakdowns

7.0 References/Further Reading

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