UNIT 9 WORK SYSTEMS DESIGN

Objectives

The objectives of this unit are to:

- get introduced to importance of job design and job standards in relation to organisational objectives
- discuss about the traditional Engineering techniques and some behavioural approaches as job rotation, enlargement and enrichment to enhance productivity and satisfaction
- study the work measurement techniques for determining the time standard for a job which is useful for costing, manpower planning, scheduling, incentives.

Structure

9.1 INTRODUCTION

This chapter presents Work Systems Design, which forms one important aspect of design of production/operations systems.

Work Systems Design involves: (i) job design, (ii) work measurement and (iii) worker compensation. Work design is closely related to other design decisions. Product Design determines the type of activities the worker will be involved with. Facilities Planning decisions affect Work Design : for example. Process layout requires broader job content than product layout.

Work Design forms one of the earliest areas of Operations Management. Initially it was viewed in the form of Scientific Management developed by F. W. Taylor. In recent years research in Work Design has developed in other directions. For example, the jobs which are expected to increase productivity are the ones which create considerable job dissatisfaction thereby creating sonic sort of dilemma for job designers. In view of the above facts, let's discuss first about the job design followed by work' measurement

9.2 JOB DESIGN

Job Design is concerned with specifying the contents and methods of job. The objective of job design is to develop a work system which is productive and efficient. In reality, Job Design answers the questions: who will do the job, how the job will be done and where the job mill be done.

Various job design approaches developed for satisfying the objectives are divided into two types:

Traditional Engineering Techniques and Behavioural Approaches.

9.2.1 Job Design Techniques

i) Traditional Engineering Techniques

- Specialisation
- Work Methods Analysis
- Working Environment

ii) Behavioural Approaches to Job Design

- Job Rotation
- Job Enlargement
- Job Enrichment
- Socio Technical Systems

i) Traditional Engineering Techniques

Specialisation:

During the scientific management era of F. W. Taylor. management tried to increase productivity through job specialisation. The rationale for_ job specialisation is that workers. who need fewer skills, can be more easily trained and lower wages can be offered for such specialised and repetitive jobs. The advantages and disadvantages associated with job specialisation are listed below.

Advantages

For Workers	For Management
1.Less responsibility	1.Lower wages
2.Little mental effort required	2.Simplified training
3.Low skill required	3.Higher Productivity

Disadvantages

For Workers	For Management
1. Boring and monotonous jobs	1. Difficult to motivate
2. Little control over work	2. Worker dissatisfaction leading to absenteeism, turnover and quality problems
3. Limited scope for advancement	

Work Methods Analysis

Methods Study is the systematic recording and critical examination of the factors and resources involved in existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

Methods Study basically deals with finding better ways of doing work and it helps improve productivity by eliminating unnecessary work, avoidable delays and other types of waste. These are achieved by

- Improved working procedures
- Improved layout
- Improved working environment
- Improved product design

The basic procedure of Methods Study consists of the following six steps:

i) SELECT the work to be studied

ii) RECORD all the relevant facts of the present/proposed method

iii) EXAMINE the facts critically

iv) DEVELOP the most practical. economic and effective method, with due regards to all contingent circumstances

v) INSTALL the developed method as standard practice

vi) MAINTAIN the standard practice by periodic reviews

SELECT the work to be studied: While considering whether a method study for a particular job should be carried out, the following factors are considered:

- economic
- technical
- human reactions

The following symptoms usually call for method study investigation:

- poor use of material, labor and equipment
- poor layout
- bottlenecks
- excessive fatiguing tasks.

RECORD the facts: In order to investigate the jobs, all the relevant facts should be available. The facts can be obtained by observations, studying the records and drawings, discussion with concerned persons in an appropriate form.

Charts and diagrams are the most frequently used recording techniques. The commonly used charts/diagrams used in methods study are outlined below.

Flow Process chart is a device for recording a process in a compact form, as a means of better understanding it and improving it. It shows the various steps or events (such as Operation, Inspection, Movement. Storage said Delay) that occur during the performance of work or during a series of; actions. The following systems are used in constructing a flow process chart:

○	Operation (example:	set up a machine, type a letter)
⇨	Transportation (example:	move material by truck, move file by a messenger)
□	Inspection (example:	examine parts for quality/quantity check papers)
D	Delay (example:	wait for lift, papers wait for filing)
∇	Storage (example:	raw material in storage, documents filed in almirahs)

The flow process chart for GEAR MAKING is shown in Figure 9.1.

Activity A

Considering your organisation, can you just examine the method study that has been under practice.

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Operations Process. chart is a process chart giving an overall picture by recording in a sequence only the main operations (O) and inspections (❑).

The **Man-machine chart** describes the activities of a man and of the machine(s) lie is tending. The chart helps in determining the number of machines each operator should work or the optimum number of operator per machine.

This chart helps in visualising the proportion of work cycle during which the operator and machine are busy or idle. Figure 8.2 shows a Malt-Machine chart for MIXING A DRINK IN A BLENDER.

Activity B

Consider the experience in your Organisation-Develop a flow process chart for the type of work you are engaged with.

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Department : Machine Shop	Process : Gear Making			Charted by : S. Gupta Project :
SUMMARY	Present Method	Improved Method	Difference	Number of Sheets : Sheet Number :
Operation	2 Nos.			Start Observation : Gear Blanks in Raw Material Store
Transportations	75 Meters			
Inspection	2 Nos.			Finish Observation : Finished Gears in Finished Goods Store
Temp Storage	1 No. (15 minutes)			
Storage	2 Nos.			

Description	Distance	Time
Gear blanks in raw material store		
To milling m/c	20 M	
Wait at milling m/c as m/c is busy		15 Min
Gear blank machined		
Inspection of gear blank		
To gear cutting m/c	15 M	
Gear cutting		
To inspection deptt.	20 M	
Inspection of gears		
To finished goods store	20 M	
Finished gears in F.G. store		

Figure 9.1: Flow Process Chart

Operator	Time (Minutes)	Machine	Time (Minutes)
Take Customer Order	0.3	Idle	0.3
Load blender	0.5	Load blender	0.5
Idle	0.6	Run blender	0.6
Empty blender	0.2	Empty blender	0.2
Serve drink	0.5	Idle	0.5

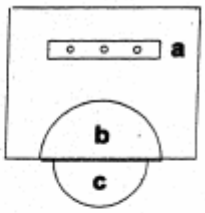
Figure 9.2 : Man-Machine Chart
Mixing a Drink in a Blender

SIMO (Simultaneous Motion) chart is used to record simultaneously on a common time scale, the therbligs (basic elemental motions) performed by both the hands of the operator. The idea behind the use of therbligs is to break the jobs down into minute elements and make improvements on the analysis of these elements by eliminating, combining or rearranging them. Some of the commonly used therbligs are:

Search	(looking for an item)
Hold	(retaining an object after it been grasped)
Transport empty	(reaching for an object)
Transport loaded	(moving hand with the object held in hand).

Simo chart is used while carrying out Micromotion Study (systematic study of human motions to perform an operation), which aims at eliminating unnecessary motions and determining the best sequence of motions.

The SIMO chart for the operation of SIGNING A LETTER is shown in Figure 9.4. Figure 9.3 shows the work place layout for the operation.



a : Pen stand
b : Writing area
c : Operator's chair

Operation : Signing a letter
Operator : Mr. R. Gupta
Deptt. : Academic Section
Charted by : Mr. S. Singh
Date : 10 Sept. 1997

Figure 9.3 : Workplace Layout for the Operation : Singning a letter

Figure 4 Simo Chart -- Signing a Letter

Description LH	Therblig	Time (Sec)	Time (Sec)	Therblig	Description RH
			5	TE	REACH FOR PEN
REACH FOR PAPER	TE	6			
			3	G	GRASP PEN
			7	TL	MOVE PEN TO PAPER
			4	P	POSITION PEN TO WRITE
HOLD PAPER	H	32	19	U	SIGN LETTER
RELEASE PAPER	RL	4			
			7	TL	MOVE PEN TO SIDE
			3	RL	DROP PEN TO DESK

Figure 9.4 : SIMO Chart

Motion Study makes use of Principles of Motion Economy, which are *used* as guidelines for designing motion-efficient procedures. These principles are classified in three categories:

i) Principles related to use of human body

ii) Principles for arrangement of work place, and

iii) Principles for the design of tools and equipment.

The **Flow Diagram** includes a plan view of the work area under consideration, *and a* line diagram indicating the path followed by the object under study *and flow* process chart symbols

Super imposed on the lint diagram to indicate what happens to the object as it passes through the process. Figure 9.5 shows the floe diagram for GEAR MAKING.

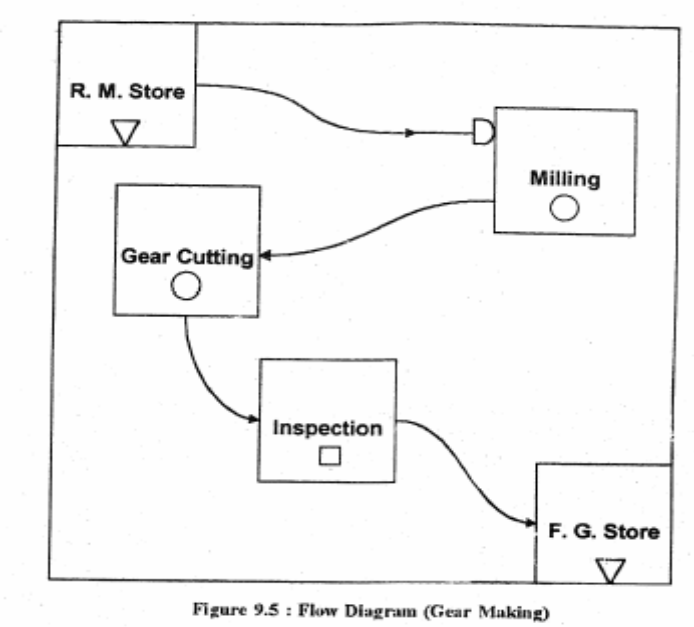


Figure 9.5 : Flow Diagram (Gear Making)

EXAMINE the facts: The recorded facts are, at this stage, systematically examined by questioning everything about the job- the way the job is being done now, the. materials that are being used, the tools and equipment, the working conditions etc.

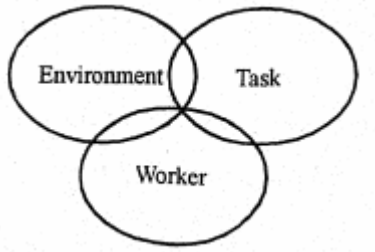
DEVELOP the improved method: Once the questions like WHY, WHAT, WHERE. WHEN, WHO and HOW are answered, the method study analyst can now try to put the findings into practice. It is often difficult to generalize the procedure for evaluating the various alternatives, since this depends upon the particular situation. Often, judgment plays a vital role. The criteria need not be confined to the quantitative factors alone. The methods study analyst is faced ,with the problem of predicting performance time, fatigue, effort, energy expenditure, monotony and job satisfaction for various alternatives. Man,, of these factors are treated as unquantiliable in the comparison of alternative work methods.

INSTALL and MAINTAIN the improved method: After the best method for performing work has been identified, this must be standardized. The motion patterns, size, quantity of materials, tools, jig and fixtures, the machine and the working conditions must be specified. All these factors, as well as, working conditions must be maintained alter they have been standardized. A written standard practice, giving the detailed account of the operations, must be followed.

Working Environment

Working environment has a significant impact on the person and on task performance. There are a number of environmental factors such as temperature, humidity, ventilation, illumination, noise etc. affecting worker performance. The work designer must know how each factor affects the person or performance, how to diagnose the problem and what solutions will be effective in different situations_

Environmental problems are the ones that involve the surroundings of the worker. There is a relationship between the worker, the task and the environment as shown below.



Environment may alone affect the worker (for example. being outside on a very hot day). But the combination of environment and task has serious influence on the worker (for example. hard work on a hot day).

The common environmental factors are outlined below.

Temperature: Human beings can perform under a wide range of temperature. However, work gets adversely affected if temperatures are outside the comfort range. Temperature problems are less problematic in offices than in factories.

Humidity: Humidity is an important variable for maintaining a comfortable working environment. Temperature levels depend on humidity levels since human beings are more sensitive to temperature variables at high humidities. High humidity requires more cooling on a warns day: and more locating on a cold day, than love humidity.

Illumination: Illumination consists of both the quantity and quality of light. Each of these may contribute to lighting problems. The amount of illumination depends on the type of job. For example, more illumination is needed for detailed work. Lighting can be classified in various ways such as:

- Primary and Secondary lighting
- General and Specialised lighting
- Natural and Artificial lighting

Primary lighting is the lighting required to perform a task, whereas Secondary lighting is light needed to move about and for safety needs.

General lighting is lighting from overhead sources over abroad area. Specialised lighting is needed for situations like checking quality defects.

Natural lighting is used widely due to its low cost Artificial lighting is used for specialised lighting.

Usually, lighting problems; arise from the quality rather than quantity of illumination. Glare and contrast are important aspects.

Glare occurs when a bright light shines in a person's eye and reduces its visibility of the object to be seen. It can be from a light source or may be reflected from the object itself. Hence, there should be proper shielding of light sources or relocation of sources of reflected glare. For example, the computer display screen should be perpendicular to the nearby window, to eliminate sources of direct or reflected glare.

Contrast is caused when the illumination level of the object is significantly different from the visual surroundings.

Solutions to lighting problems include the following:

- Controlling the light source by shielding or relocation
- Changing the illumination level
- Changing the task to require less fine visual perception
- Changing the object to control reflectance.

Noise and Vibration

Noise is unwanted sound. Noise is caused by vibration of machines as well as human. beings. Noise is annoying, thereby leading to errors and /or accidents. It can damage/ impair hearing if it is very loud. Noise limits are set by three criteria: hearing loss, speech interference and annoyance. Intermittent noise causes less hearing loss than continuous noise-because the hearing mechanisms have a chance for recovery before each new exposure. Unwanted background noise has detrimental effect on oral communication. Noise has a definite effect on work performance.

Measurement of noise levels and exposure times will indicate the extent of noise effect Measures for tackling the noise problems include the following:

- isolating the person from the noise source by distance and /or barriers.
- Modifying the exposure time. .
- Use of earplugs.

Vibration is also an important factor in job design. Vibration can conic from various sources like machines, tools vehicles, human activity. Corrective action for vibration include use of shock absorbers, padding, cushioning, rubber mounting.

Activity C

Examine the working environment at your work place which has a significant impact on your productivity. Give better solution for realocation.

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ii) Behavioural Approaches to Job Design

An effective job design is one which a person *can do.* one that *a person wants to do,* and one whose output *invaluable* to the organisation.

There are two basic schools of thought in job design: efficiency school and behavioral school

Efficiency school emphasizes on traditional engineering approaches to job design such as job specialisation, methods study etc. But most of the specialised jobs are found to be boring. monotonous and less satisfying, thereby leading to problems like absenteeism, turnover and rejects. This has been highlighted by behavioural aspects which point out that most workers do not like specialised jobs. They feel that specialised jobs are not interesting and they want more control over these jobs. This has led to attempts to make jobs interesting and meaning through approaches like Job Rotation, Job Enlargement, Job Enrichment, Socio-technical system.

Job Rotation involves assigning different kinds of jobs to workers in turn. For example, a clerk can be assigned jobs in recruitment, accounts, establishment, academic sections on a rotating basis.

Job Enlargement involves giving the worker a larger proportion of work. This is also called horizontal loading i.e. assigning additional work of same skill and responsibility.

Job Enrichment involves giving the worker work of higher skill and responsibility. For example, an assembly worker can be given the additional job of inspection.

However, before introducing the above approaches, one has to carry out further studies on the need of such changes since all workers or jobs are not amenable to job enlargement/ enrichment.

The Socio-technical Systems approach to job design attempts to develop jobs that adjust the needs of the technology to the needs of the worker and workgroup. The approach developed from studies of weaving mills in India and Coal mines in England around 1950. These studies revealed that work groups could effectively deal with many production problems better than management if they were allowed to make their own decisions. The Socio-technical approach has been adopted in many countries. The rationale underlying these studies is that the individual or work group requires a pattern of work activities incorporating Task variety, Skill variety. Feedback, Task Identity and Task Autonomy:

Task variety aims at providing optimum variety of tasks within each job. Too much variety leads to inefficiency and too less variety leads to boredom.

Skill variety enables workers derive satisfaction from using a number of different kinds of skill levels

Feedback means informing employees quickly about their performance

Task identity implies that sets of tasks should be separated from others by some clear boundary

Task autonomy enables employees to exercise some control over their work.

One of the major drawbacks of this approach is the reluctance of managers to give more authority to workers.

Activity D

Do you think job rotation & enlargement is necessary for an employee?

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9.3 WORK MEASUREMENT

Work measurement is the process which establishes the time it should take to perform a precise task, under given conditions, employing a given method and given tools and equipment when working at a defined work pace. This time is called time standard.

We note that Job Design and Methods Analysis concentrate on how the job is done, whereas Work Measurement is concerned with determining the amount of time the job should take.

From the definition of time standard. we see that the time study analyst makes dual !measurements to obtain the following:

i) the time actually taken by the operator to perform the task, and (ii) the measure of the worker's actual work pace compared to his concept of normal pace. The former constitutes the physical measurement whereas the latter is a judgment made by the time study analyst. Physical measurements can be easily made by means of various measuring instruments. But, measurement of human work is much more complicated and requires thorough understanding of work measurement and statistics.

Time standards are used by the operations manager for various purposes as follows:

i) Production planning

ii) Product costing

iii) Determining manpower requirements

iv) Determining optimum number of machines to be tended by an operator

v) Designing incentive schemes.

9.3.1 Work Measurement. Techniques

Although several techniques have been in use for developing time standards. the following methods are the most important.

i) Stopwatch Time Study

ii) Work Sampling

iii) Predetermined Data

i) **Stopwatch Time Study:** By far, the most prevalent approach, to work measurement currently *used,* is the stopwatch *time* study. In this technique, the times and rates of working *for* the job elements, carried out under specified conditions, are recorded and the data analysed *sous* to determine the time necessary for carrying *out* the job at a defined level of performance.

The stopwatch study consists of the following steps..

i) Define the task to be studied, and seek the cooperation of the worker, supervisor and management

ii) Break the job down into elements

iii) Time the job elements

iv) Determine the number of observations to make

v) Rate the worker's performance

vi) Determine the standard time

i) **Defining the Task:** The time study analyst should be thoroughly familiar with the job. He ensures that the job is being performed efficiently before setting the time standard. In other Words methods study precedes time study.

The cooperation of management and workers is very essential for the successful conduct of the time study.

ii) Determining job Elements: After defining the tasks and seeking the cooperation of all parties, the analyst breaks the job down into elements and obtains time for each clement There arc several reasons for this phase of elementalisation. First some elements not occur in every cycle. Second the worker's proficiency may not be the same for all tic job elements. Third elemental breakdown helps in preparing a manual of element limes that can be used to determine times for other jobs.

A typical breakdown of a *packaging operation* into elements is as follows:

a) Gel cartoons and wrapping paper
b) Position the wrapping paper
c) Position the part on the paper
d) Wrap
e) Place in cartoon
f) Cover cartoon
g) Put label on cartoon
h) Set the cartoon aside

In addition to the list of elements, the analyst collects some more facts on the time study observation sheet shown below. These include the name of the operator, description of the operation the department in which the operation is being carried out. Figure 9.6 shows Time Study Observation Sheet. The time study summary is presented in Figure 9.7.

iii) Timing the Elements: Once the job is broken down into different elements, the analyst proceeds with actual measurement. The timing is usually done with a standard decimal minute stopwatch as shown below. (Figure 9.8)

There are usually two methods of timing the elements: the **continuous method and the snapback** method.

In the continuous method of timing, the watch is started form zero position at the beginning of the study. The watch runs continuously and the analyst simply records the stopwatch reading at the end of each element. The elemental times are determined at the end by taking the difference between successive readings as shown below.

Element number	Stopwatch reading (minutes)	Element time (minutes)
1	0.15	0.15
2	0.48	0.33
3	0.80	0.32
4	1.02	0.22
5	1.20	0.18

In the snapback method, the watch is also started from the zero position at the beginning of the study. At the end of each reading, the analyst simultaneously notes down the stopwatch reading and snaps back (by depressing the crown). As soon as the pointer reaches zero reading, the crown is released and the pointer begins moving again. Element times are computed as shown below.

Element number	Stopwatch relation elemental times , minutes
1	0.15
2	0.33
3	0.32
4	0.22
5	0.18

DESCRIPTION OF ELEMENTS	1		2		3		4		5		6		7		8		9		10		11		12		13		NOTES
CYCLE	ET	R	ET	R	ET	R	ET	R	ET	R	ET	R	ET	R	ET	R	ET	R	ET	R	ET	R	ET	R	ET	R	
1																											
2																											
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18																											
19																											
20																											
																											Total Time
																											Average Time
																											Rating
																											Normal Time

ET : Elemental Time R : Watch Reading

Work Systems

Figure 9.6 : Time Study Observation Sheet

TIME STUDY OBSERVATION SHEET	
Department	Operation
Machine Name	
No. of Machines Operated	
Operator's Name	
Operator's No.	Operation No.
Male or Female	Part Name
Experience on Job	Foreman
	Observer
	Approved by
Time Started	Time Finished

SUMMARY				
No.	Description of Elements	Normal Time	% Allowance	Standard Element Time
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
Total Standard Time Per Cycle				
Piece Rate				

Figure 9.7 : Time Study Summary

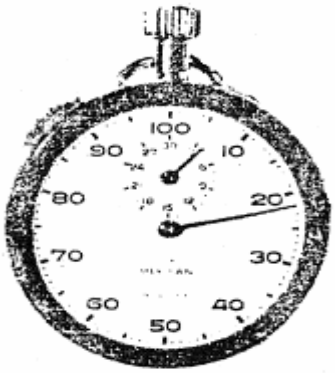


Figure 9.8 : Decimal Minute Stopwatch

iv) Determining the Number of Observations: At some point in his study, the analyst must decide if adequate number of observations have been taken. The number of cycles that must be limed depends on three things.

- Variability of observed time
- desired accuracy
- desired confidence level

This involves a sampling procedure. The rationale for determining the sample size is that it is representative as well as economic. There are statistical formulae for determining the sample size, but many of the organizations adopt empirical approaches (For example, around thirty observations are considered adequate).

v) Rating: Rating is the process in which the time study analyst assesses the rate of working of the worker with respect to his own concept of normal rate. Rating is carried out because the worker being observed may be working at a rate different from file 'normal' rate. Therefore, an adjustment factor. known as performance rating, is used by the observer to adjust the 'observed time' to 'normal time'.

$$\text{The observed time, } OT = \frac{\sum x_i}{n}$$

Where $\sum x_i$ sum of observed times

n = number of observations

Normal Time, $NT = OT \times R$.

where, OT = Observed time

R = Performance rating

This assumes that a single performance rating has been made or the entire job,

If, however, ratings are made on an element-by-element basis, the normal time is obtained by multiplying each element's average time by performance rating and summing the values:

$$NT = \sum(\overline{x_i}. Ri)$$

where $\overline{x_i}$ = Average time for element i.

Ri = Performance rating for element

For example, performance rating of 0.8 means that the pace is 80 percent of normal whereas a rating of 1.20 indicates a pace that is faster than normal by 20 percent.

vi) Determining Standard Time: Normal time is the amount of time a worker takes to perform a job if there are no delays or interruptions, Factors, such as personal delays (attending to personal needs like getting water to drink, going to rest room), unavoidable delays (like machine breakdown, tool breakage, material non-availability,. no power etc,) or rest breaks must be considered. The standard time for a job is equal to the normal time plus the allowances for such delays.

ST = NT (1+ Allowances)

Where ST = Standard time

NT = Normal time

Allowances are usually expressed as a percentage of normal time.

The following example shows the details of computation of standard time.

Example: A stopwatch tinge study of an operation yielded the following observations, for which the analyst, gives a performance rating of 1.20. Allowances for personal, fatigue and delay aspects add to 25 per cent. Determine the standard time for the operation.

Observation	Time (minutes)
1	5.20
2	5.00
3	4.80
4	4.85
5	5.15
	25.00

Solution:

Here, n = 5 R = 1.2

(a) OT 25

(b) NT = OT x R = 5 x 1.2= 6 min.

(c) ST = NT (1 + Allowances) = 6(1+ .25) = 7.5 min.

Although stopwatch time study has rendered good service in the past, there are certain obvious limitations associated with it. For example, the subjective factor of performance rating may not only vary among fines but within firms. Further, stopwatch time study is not very suitable for irregular operations as well as very short-cycle jobs. In spite of these limitations stopwatch time study, if properly conducted, can still provide the work designer with a very usefull method of measuring work.

vii) Work Sampling: Work sampling is a technique for estimating the proportion of time spent by worker(s) or machines) on various activities. Work sampling is also used as.) work measurement technique. It is based on laws of probability in which a large number of instantaneous observations are made at random intervals over a specified period of time on a group of workers machines and processes. For example, is worker may be busy or working a machine may, be busy or idle (due to breakdown. material non-availability. tool breakage. load shedding). The resulting data are the number of observations recorded for a particular activity.

Although work sampling is used for work measurement, its primary use was in ratio-delay studies which concern the proportion of time a machine is idle or the percentage of dirge a worker is working. A computer system manager may be interested in knowing the extent of utilisation of computer.

The work sampling procedure consists of the following basic steps:

i) Defining the problem
ii) Designing the work sampling study
iii) Analysing the results.

i) Defining the Problem: The main objective of the work sampling study must be clearly stated. It may be to estimate the extent of machine utilization. the proportions of tinge the worker is busy, the proportion of time during which there is load shedding.

ii) Designing Work Sampling Study:

This calls for

- description of the elements to be studied
- determining the number of observations
- deciding on the number of days/shifts needed for the study
- developing the times at which random observations are to be made
- summarizing the data

In work sampling, the instants of random observations during a specified period of time may be considered to form the sample. The sample size (i.e. number of observations to be taken) depends on the accuracy as well as confidence interval.

The formula, commonly used, for determining the sample size, n is given by

$$ps = \sqrt{|p(1-p)/n|}$$

$$ps = |p(1-p)/n|$$

where p = percentage occurrence of the activity

s = error (accuracy desired) in fraction

K = a factor, the value of which depends upon the confidence level. For example. K= 2.00 for a confidence level of 95%

n = number of observations required for the desired confidence level and margin of error.

In order to find n, the value of p is initially estimated by taking a pilot study consisting of trial observations. The value of p is revised from time to time as more observations are taken. Using the estimated value of p, the value of n is determined satisfying the confidence level and accuracy requirements.

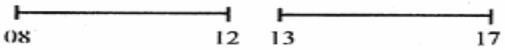
The design of the work sampling study also consists of preparing a time schedule for taking observations. Determination of a random observation schedule involves the use of a random number table. Use of these tables helps the analyst to incorporate randomness in the observation schedule. Any size number (i.e. any number of digits read as one number) can be obtained from the table. The various digits in the numbers can be suitably used for the study.

Given below is a portion of two digit random number table.

17	76	50	03	10
20	14	85	88	45
32	98	94	07	72
80	22	02	53	53
54	42	06	87	98

To use the random numbers given above, we can start at any number, say 20. The ten observation times are given by the numbers 20, 32, 80, 54, 76, 14, 98, 22, 42, and 50. The number 20 may represent 2.0 hours after the start.

Suppose the workday starts at 0800 and closes at 1700 hours with an hour break for lunch during 1200 to 130(hours.



The appropriate observation times are determined as follows:

Observation	Random Number	Corresponding time, hours	Corresponding time, hours and minutes	Remarks
1	20	8+2.0 = 10.00 hour	10:00	
2	32	8+3.2 = 11.2	11:12	
3	80	8+8.0 = 16.00	16:00	
4	54	8+5.4 = 13.4	13:24	
5	76	8+7.6 = 15.6	15:36	
6	14	8+1.4 = 9.4	09:24	
7	98	8+9.8 = 17.8	17:48	*Discard
8	22	8+2.2 = 10.2	10:12	
9	42	8+4.2 = 12.2	12:12	**Discard
10	51	8+5.1 = 13.1	13:06	

* Beyond workday (after. 1700 hrs)

** during lunch break

iii) Analysing the Results of Work Sampling: The analyst makes the observations and records them by making a series of tallies as shown below.

Activity	Total frequency	Percentage
Normal activity	800	80%
Avoidable Delays	50	5%
Unavoidable Delays	150	15%
Total	1000	100%

The above process of work sampling can be extended to determine the standard time for jobs. This is achieved by collecting additional data on production figures and the performance rating. The standard time can be determined using the following formula.

Standard time = Normal time + Allowances

$$\text{Normal time} = \frac{(\text{Total time}) \times \text{Working time} \times \text{Performance}}{\text{(duration of study)} \quad \text{in percent} \quad \text{rating}}{\text{Number of units produced}}$$

For example, the time noted from the time cards shows the duration of study as 2 days i.e. 2 days @ 8 hour per day = 960 minutes.

Number of items produced

(from inspection department) = 100 units
Working time, in per cent = 80%
Average Performance rating = 120%
Total Allowances = 20%

$$\text{Normal time} = \frac{960}{100} \times .80 \text{ x } 1.20$$

$$\text{standard time} = \frac{960}{100} \times .80 \text{ x } 1.20(1+.20)$$

$$= 11.06 \text{ minutes}$$

Work sampling , when compared with stopwatch time study, presents a number of advantages such as follows:

- No timing device needed
- Many operators or activities can be studied simultaneously
- No disruption of work
- Suitable for non-repetitive jobs
- Study spread over a long period of time, hence more representative
- Less fatiguing and less tedious study
- Less costly

However, work sampling is not without limitations. The noteworthy limitations, as compared to stopwatch time study, are as follows:

- Not suited for short, repetitive jobs
- Cannot provide much detailed information about job
- The worker may change work pattern on seeing the observer.

iii) **Predetermined Data:** When a large number of accurate time studies is required for recurring work involving many similar elements, developing them by individual time studies or by work sampling studies would be very expensive and time consuming. Hence, in such situations, it is better to consider analysing the smaller elements

initially and recording the results for further use in synthesizing times for work that contain these types of elements.

There are two basic types of predetermined data: Macrodata and Microdata.

Macro data (also referred to as standard data system) is applied to much more aggregated work activities such as packing a box, loading a machine etc. Micro data (also known as Predetermined Motion Time System) is expressed in terms of elemental body movements like reach, move, grasp, turn, release etc.

When there is a large number of different short cycle jobs involving many similar activities, macro-data often provides useful method of organising time estimation data.

A Predetermined Motion Time System (PMTS) is an organised body of information, procedures and techniques employed in the study and evaluation of work elements performed by human power in terms of the method or motion used, their general and specific nature, the conditions tinder which they occur, and the application of prestandardised or predetermined times which their performance requires.

When using PMTS, manual work is considered to be a series of elementary motions, such as reach, grasp, posit ion, disengage. Charts are available which indicate the time taken for an average worker to complete various elementary motions. Since almost any physical work can be broken down into an appropriate listing for micromotions, these charts of PMTS allow organisations to compute time estimates for jobs before they are actually performed.

The shortcomings of stopwatch time study have been indicated earlier. PMTS have a number of advantages over stopwatch time study such as follows:

i) The times are based on consistent standards reproducible at any time by any individual.
ii) The rating factor is build into it and is not just the assessment of one person but many.
iii) Times are based on very large samples and hence more reliable.
iv) Exceedingly short cycle work is easily timed by PMTS; in fact the shorter the cycle, the easier is the measurement.
v) The method of measurement is more acceptable to workers and management.

The important PMTS currently in use are the following:

- Methods -Time-Measurement (MTM)
- Work Factor (WF)
- Basic Motion Time Study (BMT)

The main uses of PMTS are for evaluation of work methods and establishment of time standards.

9.4 COMPENSATION

Wages have always been the basic reward for labor. Over the years, two basic types of wage payment plans are available to employees: Time-based Payment and Output-based Payment. The former is known as time payment and the latter is known as incentive payment.

Most employees are paid on the basis of time (hourly or monthly). Output-based systems offer some sort of incentive either to an individual or to work group.

Time-based payment provides for compensation of employees according to the time they devote to the organisation. This system is widely used for office, administration, R&D and other situations. Whenever worker is highly variable, creative or difficult to measure, time-payment are favoured.

Incentive payments are made to reward workers for their output. Some workers produce more under incentive system than they might under a time-based system. Workers may like incentive system since they expect a relationship between their efforts and their earnings.

The merits and demerits of time-based systems are summarized below:

	For Management	For Workers
Advantages	* Easy to manage	* Steady income
	* Easy to compute wages	* Less pressure to produce more
	* Steady output	
Disadvantages	* No incentives	* Extra effort not rewarded.

The merits and demerits of **output-based** systems are:

	For Management	For Workers
Advantages	* More output	* Opportunity to earn more
	* Less unit cost	* Wages related to efforts
Disadvantages	* Quality may suffer	* Pay fluctuates
	* Wage Computation more difficult	* May be penalised for low output (beyond his control)

The desirable features of an incentive system are

- Simplicity
- Ease of use
- Consistency
- Fairness
- Wide coverage

Incentive systems are of two types : Individual and Group. Various types of individual incentive plans are in use. The simplest form of individual incentive plan is the straight piece rate system, where a worker's wage is directly proportional to his output. Now-a-days the guaranteed base wage is incorporated in the piece-rate system, which ensures a minimum or basic wage to workers irrespective of output. They get incentive beyond a specified output norm.

Group incentive systems are applicable where the output of individuals cannot be easily identifiable. For example, group incentive is applicable to groups of workers engaged in operation assembly lines, material handling etc. Although some plans reward the group on the basis of output, others are rewarded for reduction of waste and costs increase in equipment utilization.

Wage incentives can help the organization save on total cost if they generate higher productivity. However, incentive plans cost money to administer, and they are difficult Io apply to nonstandard (job shop) activities and machine-paced activities. Though a variety of compensation plans are available, it is important to carefully choose a plan as the compensation plan is very important to both management and workers.

Activity E

What is your experience with individual incentive system and group incentive system? Give comparison in terms of productivity.

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9.5 SUMMARY

Work systems design involves. job design. work measurement and compensation. Job design is concerned with the job content and work methods. The various job design approaches are classified into traditional engineering approaches and behavioral approaches. Traditional engineering approaches include Specialisation, Methods Study and Ergonomics. The Behavioral approaches consist of Job Rotation, Job Enlargement, Job Enrichment and Socio Technical Systems.

Work measurement is concerned with determining the time standard for a job. Time standards are useful for various purposes such as costing, manpower planning, scheduling, incentive plans. Stopwatch Time Study. Work Sampling, and Predetermined Data are the commonly used work measurement systems.

Various types of compensation plans are in use. They include individual as well as group incentive plans. One has to carefully choose the right compensation plan as the compensation plans are very important to both management and workers.

In conclusion, it is very important for management to snake work system design a key element of its Operations Strategy.

9.6 SELF-ASSESSMENT EXERCISES

1) Discuss the relationship between work measurement and job design. While typically follow the other? Why?
2) Contrast operation charts, activity charts, and flow process charts.
3) Explain the difference between the job design and job statandards.
4) Contrast job enlargement and job enrichment. Are they mutually exclusive?
5) Select two uses of time standards. Explain how the time standard could help a municipal police department in a city of 40.000 persons for the two uses you have selected.
6) Explain the predetermined time study approaches to work measurement.
7) Why pre job standard compartment ?
8) A speciality wood products company in eastern Kentucky manufacturers handmade miniature wooden dogs. This Dandy Dogic product line is hand-carved, varnished. labeled, and boxed, all by the same person. But there are wide variances in quality and performance times, which management is no longer willing to accept. In the *hope of* establishing a standard time, management has done a direct time study focusing on the two-inch walnut beagle. The results are shown below. For now, hand-carving is being eliminated from the study. The firms' allowance fraction is .10 . Establish a standard time for the remainder of the job.

Task times for Dandy Dogic (in minutes)

	Cycle				
Job Element	1	2	3	4	Worker Rating (in percent)
Tarnish	5	4		4	105
Label	0.5	0.4	0.3	0.5	95
Box	2	2	1	2	95

9) American Commerce's labor standard for over-the-road truck drivers is 320 miles/8-hour shift. Current wages are $8/hour under a nationwide contract. The assigned drivers from the Cleveland terminal logged 3,525 miles the first week of April and recorded 922 hours of work. A no-overtime policy is in force for Cleveland-based drivers.

   a) What is the labor efficiency variance for the first week of April?

   b) The American Commerce shop steward (driver union representative) contends that since the drivers log primarily noninterstate miles, the standard should be 10 less, or 288 miles/day Operating management would like a comparative labor variance for the first week in April. What do these labor variances actually mean to management?

10) Direct time study for a job resulted in the following lilacs.

Cycle	Average Cycle Time (in minutes)
1	1.321
2	1.411
3	1.704
4	1.175

A predetermined time standard was set at 2,128 TMU/cycle, which converts to 1.275 minutes/cycle. What time standard would you recommend? Justify your choice.

11) Job analysis reveals that during a typical 8-hour workday a man-machine operation typically experiences various unavoidable delays totaling 40 minutes and one equipment setup changeover of 20 minutes. Operators need 2-'ninnies for personal time and take two 15-minutes coffee breaks. Standard time per cycle (to produce one unit) is 10 minutes. How many units are produced by an operator rated at 85 per cent? At 115 per cent?

12) A student facing midterm exams decides to start studying in earnest. After one day in the library,- the student is dismayed to find that, at her current rate of studying, she will not be ready to take the exams until four days after they are over/ A friend volunteers to do a work sample and finds the following.

Studv Period	Number Of Observations	Number of Observations During Which Studying Occurred
1	11	8
2	23	11
3	7	3

As a percentage of her study period time, what portion of time is she studying?.'

13) Filing clerk in a state department of welfare were considered to be working any time they had paper in their hands. Observations were made for seven days. Results are given below. What portion of time is spent in working'? What work measurement technique is this? How might one alternatively define working?

Day	Number of Observations	Observation During Which Work Occurred
1	14	10
2	17	10
3	10	5
4	23	14
5	14	10
6	11	9
7	19	13

14) Several laboratory technicians in a hospital are responsible for running the highly automated "Chemistry 12" blood profile test. An experienced technician was monitored over a two-week period (170 hours). The analyst studying the job found that the technician performed 412 blood profile tests, working 60 per cent of the time and idle the rest. Sonic idleness was due to waiting for the automated equipment to complete the test. The technician was rated at 85 per cent, but the analyst was uncertain about this rating because of the automated equipment. Allowances arc set at .10.

a) Determine a standard time for a standard blood profile test.

b) How coed the analyst be more certain about the worker rating?

15) A manufacturer is considering buying one of two types of equipment; type A or type D. Initial equipment cost is $10,000 for either A or B. Operating costs are estimated as follows:

	A	B
Maintenance (per month)	$750	$500
Supplies (per unit)	0	.052
Operator *(*per hour)	9	9

The companies selling the equipment each arranged for experimental demonstrations, in which stopwatch time studies of operator/machine performance for five cycles were measured, with the following results:

	Task Times (in minutes) for A					Task Times (in minutes) for B				
	Cycle					Cycle				
Task	1	2	3	4	5	1	2	3	4	5
Load Machine	0.32	0.29	0.28	0.31	0.30	0.30	0.27	0.25	0.22	0.21
(machine paced)	2.73	2.61	2.68	2.71	2.63	2.62	2.57	2.59	- 2.51	2.54
Unload Machine	0.14	0.10	0.09	0.12	0.11	0.12	0.09	0.10	0.11	0.09
Inspect product	1.21	0.08	1.29	1.15	1.20	0.92	0.94	0.86	0.79	0.87
Apply label to Product*	-	-	-	-		- 0.05	0.04	0.05	0.05	0.04

*Label application is automatic for D and manual for B.

The analyst rated the operator at 115 per cent on equipment D and 110 percent on B. It is estimated that during their daily 8-hour shift, operators will receive two 15-minute coffee breaks. Unavoidable delays are estimated to be 40 minutes for D and 25 minutes for B daily. Evaluate the two alternatives and justify your recommendation A or B.

16. A post office mail room receives mail and cancels the postage stamps. After first simplifying work, you make d direct time study of the simplified job and obtain the following times in minutes:

		Cycle				
` Tast	Description 1	2	3		4	5
1.	Empty mail bags	.16	.31	.14	.15	.16
2	Sraighten mail	.60	.60	.60	:60	.60
3	Carry trays to reader	.34	.36	:35	.37	.38
4	Cancellation machine	.50	.50	.50	.50	.50
5	Empty trays	.24	.24	.48	.27	.25

You further determine the following information about this job:

1) Tasks 2 and 4 are machine-controlled and cannot be speeded up by the operator.
2) You observed two irregularities while timing the job. These task times vary by more than 20 percent of each task's *average* time.
3) You rated the operator at 120 per cent when he was working.
4) Management and the worker's union have negotiated the following allowances for this job:

Personal-30 minutes/8-hour shift.

Unavoidable delay-40 minutes/8-hour shift

Fatigue-.10

5) An operator on this job earns $5/hour.

6) Material cost per unit is $.50.

7) Total overhead cost is added in at a rate of 150 percent of the sum of direct labor and material cost.

   a) How many pieces should each operator produce during an 8-hour shift?

   b) What is the total standard cost per pieces?

17) As d bank officer assume you have your bank tellers count out $100 bank packs in denominations of six $ 10 bills, seven $5 bills, and five $1 bills. The purpose of this job is to supply our bank's night teller service with this bankpack: Suppose a continous stopwatch time study yielded the following data.

Cumulative task times (in minutes)

		Cycle								
Task	Description	1	2	3	4.	5	6	7	8	Worker Rating (in per cent)
1	Count 6 $10s	.12	.66	1.40	1.95	3.26	3.91	4.52	5.05	110
2	Count 7 $5s	.27	.84	1.40	2.12	3.41	4.08	4.66	5.21	115
3	Count 5 $1s	.38	.96	1.51	2.20	3.52	4.18	4.74	5.29	105
4	Count $100s	.56	1.09	1.80	2.41	3.80'	4.36	4.94	5.48	110
5	Place in Chute"	-	-	-	3.13	-	-	-	-	90

Teller had to recount because of error.

Occurs once every 10 cycles.

The allowances for this job are set at .15.

a) What is the normal tile for this job?

b) What is the standard time for this job?

c) What is the standard output in terms of bankpacks/hours?

d) How long in terms of work hours) would it take to package 500 bankpacks, if the tellers assigned to the job worked at a pace on the average at 115 per cent?

9.7 FURTHER READINGS

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