41 Method Study

41.1. INTRODUCTION TO WORK STUDY

Work study is not a new concept. Since the beginning of human race, there had always been a tendency to bring certain improvements in their activities. But this has been recognised at a very later stage. Numerous early pioneers who contributed to the emergence and development of work study are : Frank B. Gilbreth, Fredrick W. Taylor, Beduax, Henry L. Gantt, Harrington Emerson, Halsey, Rowan and others.

Work study is one of the most important management techniques which is employed to improve the activities in the production. The main objective of work study is to assist the management in the optimum use of the human and material resources.

It has three aspects :

(1) More effective use of plant and equipments.

(2) More effective use of human effort.

(3) Evaluation of human work.

Work study is simply the study of work. It is the analysis of work into smaller parts followed by rearrangement of these parts to give the same effectiveness at lesser cost. It examines both the method and duration of the work involved in a process.

The nature and objective of work study can be defined by various ways as given below :

1) Work study is primarily concerned with discovering the best ways of doing jobs and with establishing standards based upon such methods.

2) Work study is a technique used to minimise cost either by designing work for high productivity or by improving productivity in existing work through improvements in current methods and by reducing ineffective or wasted time.

3) Work study may be defined as the analytic investigation of the methods, conditions and effectiveness of industrial work, and thereby the determination of the ways in which human efforts may most economically be applied.

According to British Standard Institute, "Work study is a generic term for those techniques, particularly method study and work measurement, which are used in the examination of human work in all its contexts, and which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement".

It can be simplified as a term which embraces the techniques of method study and work measurement employed to ensure the best possible use of human and material resources in carrying out a specific task.

Work study is thus especially concerned with productivity. It is most frequently used to increase the amount produced from a given quantity of resources, with little or no further capital investment.

Work study is also recognised as "Time and Motion Study". According to Taylor, there was a great difference in these two terms. Work study has got a broader concept while time and motion study was mainly used for determining time standards and motion economy.

Importance/Objectives of Work Study

Work study is a service to management and supervision and is aimed to achieve following objectives :

(*i*) It is a mean for raising productivity of an industry by re-organisation of the work, involving little or no capital expenditure at all.

(*ii*) It is used to determine the standards of performance on which effective planning and control depends.

(*iii*) It follows a systematic approach which ensures no related factor is overlooked.

(iv) It results in better workplace layout, neat and clean working environment resulting in minimum movement of workers and materials.

(v) It results in saving and efficient use of human and material resources by increasing output and reducing scrap, rework etc.

(vi) It eliminates unnecessary human movements.

(vii) Results in improved safety.

(viii) Reduction in fatigue and health hazard.

(ix) It guides to determine the level of skill in the workers for implementing the incentive based wage system.

(x) It helps to minimize unit cost by proper selection and use of machine, processes etc.

Pre-requisites of Conducting a Work Study

Work study is not a substitute for good management and never can be. It is one of the tools used by the management. One can use it to analyse the industrial problems in the most scientific way. Work study itself will not make bad industrial relations good, although wisely applied it may often improve them. Experience shows that the application of work study in an industry can bring improvements of productivity provided relations between management and workers are reasonably good. The workers must have confidence in the sincerity of the management towards them. Before carrying out work study to bring any change in the system, the workers must be taken into confidence. They should not feel that they are kept in dark. If the workers have confidence in the integrity of management, they will not offer resistance to implement changes.

Good human relations and working conditions are thus two important pre-requisites for successful application of work study.

Relationship between Method Study and Work Measurement

(1) Method Study. "Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs".

(2) Work Measurement. Work measurement is the application of techniques designed to establish time for a qualified worker to carry out a specified job at a defined level of performance.

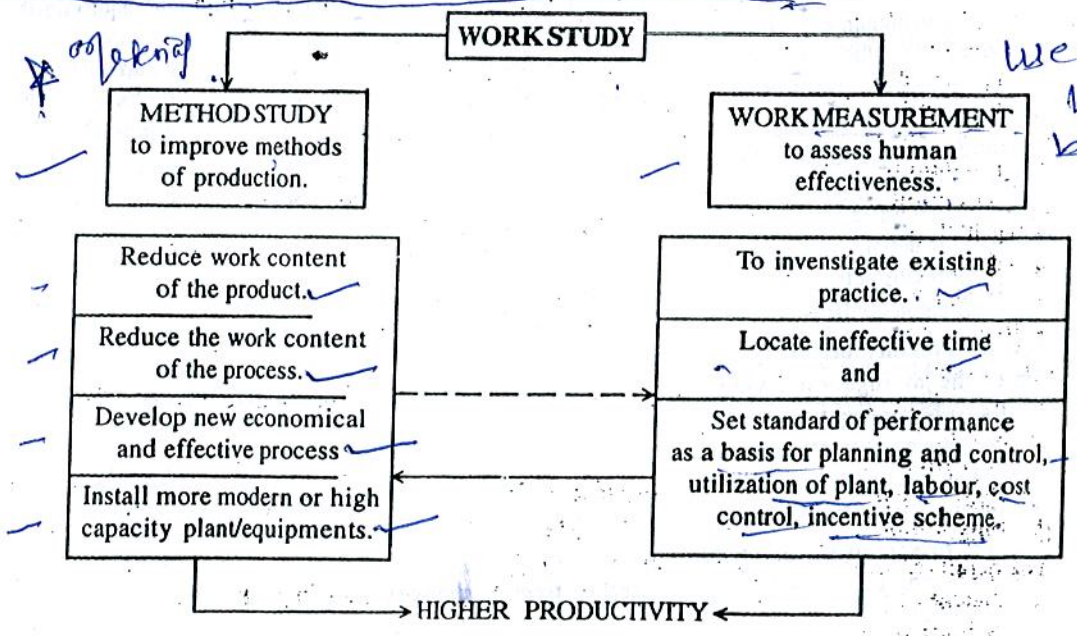


Fig. 41.1. Relationship between method study and work measurement.

Method study and work measurement are, therefore, closely linked. Method study is concerned w the reduction of the work content of a job or operation. While work measurement is mostly concerned with investigation and reduction of any ineffective time associated with it and with the subsequent establishm of time standards for the operation, when carried out in the improved fashion, as determined by method stu The relationship of method study to work measurement is shown simply in figure 41.1.

Both method study and work measurement are themselves made up of a number of different techniq Generally method study should precede the use of work measurement, but when time standards for output being set, is often necessary to use one of the techniques of work measurement, in order to determine w ineffective time is occurring and what is its extent, so that the management action can be taken to reduc before method study is begun. Equally, time study may be used to compare the effectiveness of alternat methods.

41.2. METHOD STUDY

Method study has already been defined, but the definition is worth repeating at this point.

"Method study is the systematic recording and critical examination of existing and proposed ways o doing work as a means of developing and applying easier and more effective methods and reducing costs"

From the above definition, it is clear that method study is concerned with the development of efficien and economical work methods. Proper development of these methods calls for the co-operative efforts of th design engineer, process engineer, and method analyst. There is a continuing need for analyzing existin methods even in the case in which special efforts are made to develop efficient orginal work method. Th reason for this is that the best methods to day may not necessarily remain the best method after some period Subsequent investigations may reveal that more economical materials are available, more efficient machines tools, jigs and fixtures have been designed ; better inspection methods have been evolved, more satisfactor material handling equipment can now be procured ; the existing plant layout is obsolete because of change in the product design and so on. Therefore, opportunities to improve upon existing methods always exist because of technological developments.

The Objectives of Method Study :

1. The improvement of processes and procedures.
2. The improvement of factory, shop and work place layout and of the design of plant and equipment
3. Economy in human effort and reduction of unnecessary fatigue.
4. Improvement in the use of materials, machines and manpower.
5. The development of better physical working environment.
6. To find the best way of doing a job.
7. To standardize the best method.
8. To train the individual worker in its practice as per standardized method.
9. Reduction of waste and scrap, improvement in quality.
10. Effective material handling.
11. Greater job satisfaction, higher standards of safety and health.
12. Improvement in the flow of production and processes.

Pre-requisites for method study :

(1) Aim of the investigation giving a scope of study and special limitations to be observed.
(2) Results to be expected.
(3) Expected time and cost of investigation.
(4) Basis of survey estimates indicating present situation.
(5) Programme of investigation technique required.

The details of present situation should indicate :

(*a*) Nature of product i.e. whether standardized or frequent changes in design.
(*b*) Volume of output.
(*c*) Labour employed (direct or indirect).

its requirements. The main purpose of such an assigned plan is to ensure that technical parameters are retained for long periods (at least 10–20 years) and to guarantee that all countries can access the geostationary orbit when needed. Planned allocations are attractive for broadcast service where thousands of terminals may be used by the public who do not want frequent changes. In fact

progress to the implementation stage.
7. Any changes to the assignment, which may be required at a later stage, are re-coordinated.

As an example, the main FSS allocation bands existing at present are summarized in table 3.1. The table is included only to provide a general idea and no

(*d*) Grade or skill level of operators and labour.
(*e*) Available plant and equipment.
(*f*) Layout of plant and work place.
(*g*) Mode of payment to the labour.
(*h*) Relative importance of various costs such as :
Labour cost, Material cost, Processing cost, Handling cost etc.

The preliminary information helps to analyse the situation and plan the strategy for further detailed work-study i.e. investigation.

41.3. BASIC PROCEDURE/STEPS IN METHOD STUDY

The techniques of method study aim at doing three things :
(1) To reveal and analyse the true facts concerning the situation.
(2) To examine those facts critically.
(3) To develop from the examination of the facts the best answer possible under the present circumstances.

In examining problem there should be a definite and ordered sequence of analysis. Such a sequence may be summarised as follows :
(1) Define the problem.
(2) Obtain all the facts relevant to the problem.
(3) Examine the facts critically and impartially.
(4) Consider the courses open and decide which to follow.
(5) Act on the decision.
(6) Follow up the development.

The basic procedure for method study, selecting the proper steps, is as given below :
(1) **Select :** the work to be studied.
(2) **Record :** all the relevant facts of the present or proposed method by observation or analysis.
(3) **Examine :** the recorded facts critically and challenge everything that is done, considering in turn; the purpose of the activity, the place where it is performed, the sequence in which it is done ; the person who is doing it and the means by which it is done.
(4) **Develop :** the most practical, economical and effective method considering all the circumstances.
(5) **Define :** the new method so that it can always be identified.
(6) **Install :** that method as standard practice.
(7) **Maintain :** that standard practice by regular routine checks.

Select (Selection of work for study) :

While selecting the work for method study investigation, following factors must be considered :
(*a*) Economic considerations, (*b*) Technical considerations.
(*c*) Human reactions.

Economic considerations will be important at all stages. It is obviously a waste of time to start or to continue a long investigation if the economic importance of the job is small, or if the job is expected to run for a short duration of time. The cost of study, the loss of time due to the investigation, the cost both short-term and long-term associated with the prospective changes in the recommended working method of the job should be carefully estimated and examined.

Obvious early choices are :
(*a*) "Bottlenecks" which are holding up other production operations.
(*b*) Movement of material over long distances between shops.
(*c*) Operations involving a great deal of manpower and equipment.
(*d*) Inconsistencies in quality.
(*e*) Highly fatigued work.
(*f*) Operations involving repetitive work using a great deal of labour and liable to run for a long time.

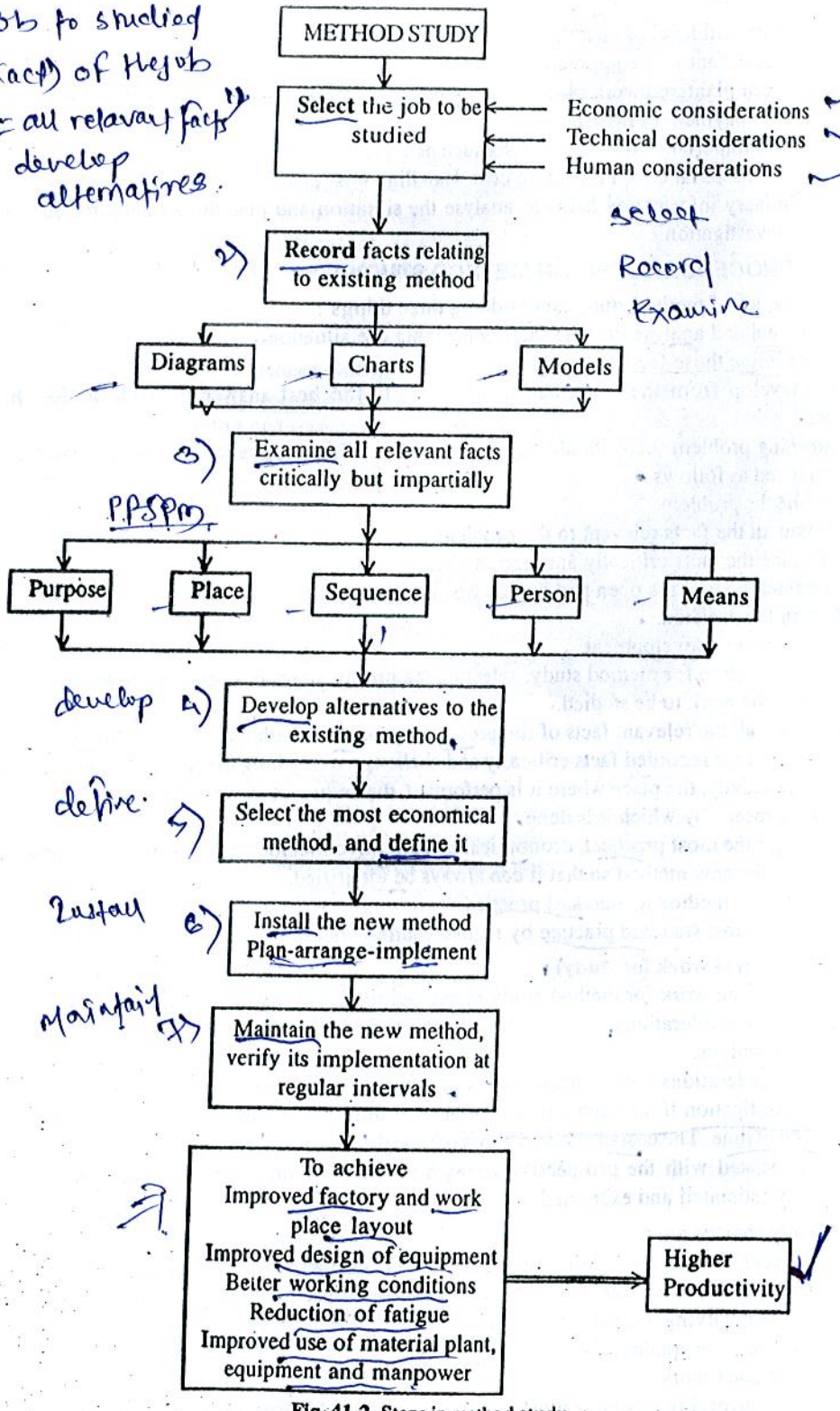


Fig. 41.2. Steps in method study.

Technical considerations. The most important point is to make sure that adequate technical knowledge is available to sort out bottleneck of a problem or to overcome manufacturing difficulties. For example, if the rate of production is slow, then to solve this problem one should have expert knowledge about :

- The speed, feed and depth of cut and such other machine parameters.
- The alternative cutting tool, machines, materials, operations etc.
- The skill required to perform the job etc.

Human reactions. Mental and emotional reactions to investigations and changes of method should be anticipated ; if the study of a particular job appears to be leading to unrest or ill feeling leave it alone, even though it is most economical. Method study will be more readily accepted by the workers if the subject selected for method study can improve the working conditions, reduce the effort and fatigue of the workers and helps to increases their wages.

While selecting a job for method study, it will be helpful to have a list of points to be covered during the analysis. Such list may deal with the design and specification of products, their operations, persons, equipment layouts, what savings or increase in productivity may be expected from a method study etc.

41.4. RECORDING TECHNIQUES

The next step in the basic procedure, after selecting the work to be studied, is to record all the facts relating to existing method. The success of whole procedure depends upon the accuracy with which the facts are recorded, because they will provide the basis of both the critical examination and the development of the improved method.

Purpose of recording can be summarised as follows :

(1) To enable the process to be clearly understood.
(2) To present the existing facts for analysis.
(3) To submit the proposals to the management in a form which can be easily understood.
(4) To guide supervisors and operators regarding detailed operating instructions.

According to the nature of the job being studied and the purpose for which the record is required, the following are the most generally used techniques. By means of one or more of these techniques every normal type of activity can be recorded in the appropriate degree of details required.

A Charts : Indicating process sequence.
- Outline process chart.
- Flow process chart – Man type.
- Flow process chart – Material type.
- Flow process chart – Equipment type.
- Two – Handed process chart.

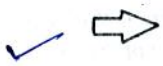
B Charts : Using a time scale.
- Multiple activity chart.
- Simo Chart.
- P.M.T.S. Charts.

C Diagrams indicating movement and models :
- Flow diagrams.
- String diagrams.
- Cycle graph.
- Chrono-cycle graph.
- Travel chart.

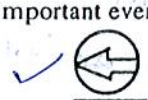
Two and three Dimensional models.

Process Charts constructions :

The construction and interpretation of process charts are simplified by the use of two or more of the following symbols. These symbols divide the task selected into five functions ; and all activities can be so divided.

Symbols	Activity	Predominent Result
	Operation	It indicates main steps in a process, method or procedure. Usually the part, material, or product concerned is modified or changed during operation, *e.g.* cutting a bar on a power hacksaw, filing, facing etc.
	Inspection	Inspection is an act of checking for correctness of the quantity or quality of the items. *e.g.* gauging piston pin or checking the hardness of a mild steel piece etc.
	Transport	This indicates a movement of workers, materials, or equipment from place to place. *e.g.* m.s. bar being sent from stores to machine shop, Gear blank from lathe to milling machine etc.
	Delay (Temporary storages)	Delay occurs when something stops the process and product waits for next event (operation). Ex. power failure, machine breakdown etc.
	Storage	It indicates when any object is intentionally retained in a state or location and removal of the object requires proper authorization. Ex. milling cutters lying in tool store, finished goods ready for sell etc.

In addition to the basic symbols discussed above, there are symbols for combined activities also. The important event has the outer symbol.

	Operation-cum-Transportation	Example – Articles are being painted as they are transported by the chain conveyor.
	Inspection-cum-Operation	Example – A powder milk tin is being weighed (inspection) as it is filled. Both the events occur simultaneously.

Outline process Chart :

The outline process chart gives the overall picture of the process. It is a graphic representation of the points at which materials are introducted into a process and of the sequence of all operations and inspections associated with the process.

The general flow of the process is indicated by vertical lines, while horizontal lines indicate the material being introduced.

The chart does not show where work takes place or who performs it. It is only concerned with operations and inspections, hence only two of the five symbols are used in this type of chart.

Objectives of operation process chart :

(1) It helps to decide whether a further and more detailed record is needed.

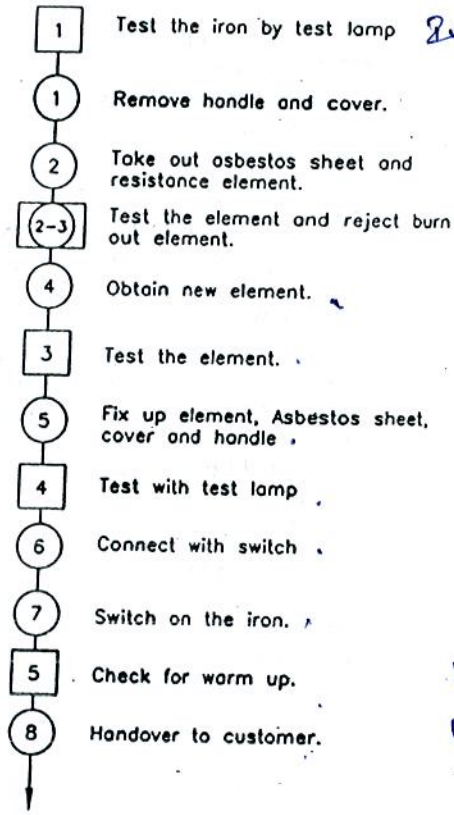
(2) It is used in the design stage to assist the layout of the plant and location of one department with respect to the other.

(3) It helps the analyst to visualize the process for examination as a means for better understanding and improvement of the process.

(4) It shows clearly the relationship between various parts and materials which enter the final assembly.

Operation process chart of an assembly contains a large number of lines, one for each component. The flow line for the main component to which the largest number of components are assembled is charted on the extreme right hand side. The flow lines of other components are then placed on the left of the main flow line considering the order of assembly of components. The individual flow lines are made to be fed into the main flow line at the stage at which their components are assembled. Each flow line records principal operations and inspections performed on the component it represents.

Outline (Operation) Process Chart :
Task. Replacement of Burnt Element of Iron.
Method : Present/proposed Chart begins.....
Charted by :..... Chart ends.....

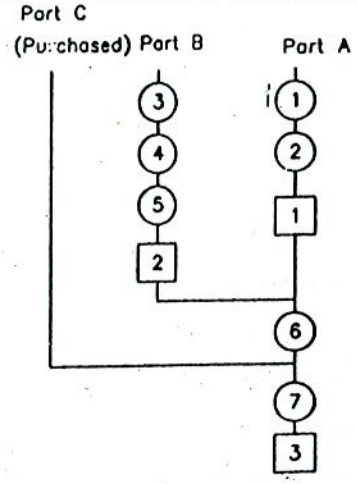


SUMMARY

No. of Operations	8
No. of Inspections	5
Total No. of Activities	13

Fig. 41.3. Outline process chart.

The symbols (operations and inspections) are numbered independently but serially starting with numbering of symbols in main flow line. The serial numbering, beginning with 1 for the first symbol on main



SUMMARY

No. of Operations	7
No. of Inspections	3
Total No. of Activities	10

Fig. 41.4. Typical operation process chart.

flow line is continued down the line until the point where next component joins it. The symbol on the main flow line after the junction of the main and the other flow line is assigned the next higher serial number. The brought out parts are also shown in the operation process chart. The flow line of the brought out part terminates at the point the part enters the assembly. This procedure is illustrated in the Fig. 41.3.

Flow Process Chart :

Once the overall picture of the process has been established it is possible to go into greater details.

Flow process chart is defined as a graphic representation of all operations, inspections, transportations, delays, and storages occurring during a process or procedure which includes information considered necessary for analysis such as time required, quantity and distance moved etc.

Types of Flow Process Chart :

(*a*) Man type – It records what the worker does.
(*b*) Material type – It records what happens to the material.
(*c*) Equipment type – It records how the equipment is used.

Flow process chart is an amplified form of operation process chart. All the detailed information regarding the process is to be recorded i.e. all the five symbols are used to write down the details of the activity. It is always recommended that a chart should represent the flow of either man, material or machine at a time.

This chart is very important for the analysis purpose because it gives a complete picture of what is being done and helps the man to understand the facts and their relationship to one another. All the details which may appear on the chart must be obtained from direct observations. Further, wherever the transportation symbol is used, the actual distance covered by man, material or machine should be recorded.

Objectives of the Flow Process Chart :

(1) To visualize the complete sequence of events occurring in a process.

(2) To study the events in a systematic way for the complete analysis of the manufacture of the component part, for the following purposes :

(*a*) To improve the layout. (*b*) To improve material handling.
(*c*) To reduce delays. (*d*) To eliminate, combine or re-arrange the events in a systematic way.

(3) To compare between two or more alternative methods.

(4) To select operations for detailed study.

Flow Process Chart.	**Material Type**
(Material - Hose pipe)	(Present method)
Job	Watering the garden.
Chart begins :	Hose lying in the cupboard.
Chart ends :	Hose lying in the cupboard.
Charted by :	Mr. Y.
Date :	

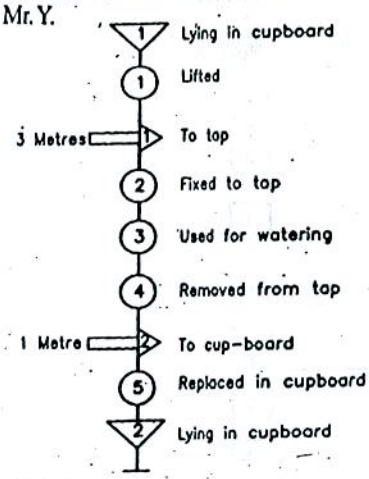


Fig. 41.4. Flow process chart.

Summary

Event	No.	Time	Dist.
○	5	–	
⇨	2	–	4 mtr.
▽	2	–	

In industries the flow process chart is usually drawn in the manner as given below.

Flow Process Chart "Material Type"

Job – Making the casting ready for machining.
Chart begins – Casting lying in foundry.
Chart ends – Castings ready for machining.

Activity	Operations ○ □ ▽ D ⇨	Distance moved mtrs.	Time (Minutes)	Remarks if any
Casting laying in foundry store		–	–	–
Moved to gas cutting machine		10	3	By trolley
Wait, Cutting machine being set		–	5	–
Risers cut		–	20	–
Wait for trolley		–	10	–
Moved to Inspection department		6	2	
Inspection before machining			15	By trolley
Moved to machine shop		10	3	

A portion of the flow process chart (Material types) showing flow of product.

Summary

Event	No.	Time	Dist.
○	1	2	–
□	1	15	–
▽	1	–	–
D	2	15(5 + 10)	
⇨	3	8	26

Fig. 41.5. Flow Process Chart (Material type).

Flow Process Chart "Man" type :

Job	–	Writing a letter using a shorthand typist.
(Present method)		
Chart begins	–	Typist in own office awaiting dictation.
Chart ends	–	Typist puts letter and copy in out tray.
Typist office	–	6 mtrs ---------- Manager's office.

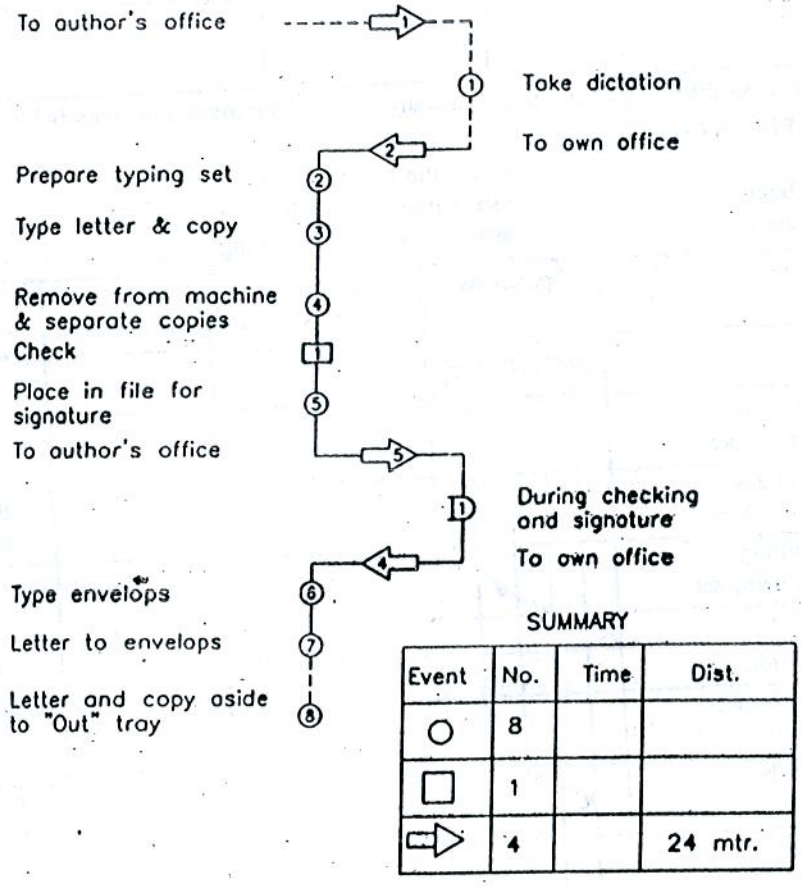


Fig. 41.6. Flow Process Chart (Man type).

Two Hand Process Chart : (Left and Right Hand Process chart)

After studying the operation process chart and flow process chart, it is the proper time to investigate the specific operation in order to improve it. It is a motion study where the study is done to analyse the motions used by the worker in performing an activity. The objective of this investigation is to eliminate or reduce the unwanted motions and to arrange the remaining motions in a best sequence.

The two hand process chart is "a chart in which the activities of a worker's hand are recorded, in their

relationship to one another". It is commonly used for repetitive and short operations. Same symbols are used as in the case of other charts. But in this case the meaning of the symbols is changed accordingly.

Symbol	Activity	Description
○	OPERATION	An operation occurs whenever the hand grasps, releases or assembles tool, material, component etc.
⇨	TRANSPORT	Transport occurs when the hand moves from one position to another at the work place (towards or away from the work, tool or material).
D	DELAY	Delay occurs when the hand is idle in the sense that it is not performing any activity.
▽	HOLD	The term storage is not used in connection with the two handed process chart. Instead, the symbol is redesignated as hold. A hold occurs when the hand holds an object so that the other hand may be able to do something to that object.

The symbol of inspection is not generally used in this connection.

The act of making the chart enables the work study man to gain an intimate knowledge of the details of the job. The chart itself enables him to study each element of the job and its relation to other elements. From this study, ideas for improvement are developed. Different ways of simplifying the work may be found, if they are charted, they can compared easily to find out the best method. The two handed process chart can be applied to a great variety of assembly, machining and electrical jobs. It helps to visualise the complete sequence of activities in a repetitive task of short duration performed within the confines of a work place.

Procedure for preparing two-handed process chart :

1. Before start of recording, study the operation cycle few times.
2. Observe one hand at a time and record.
3. Record few symbols at a time.
4. Start observing and recording at a position which could be easily distinguished. The action of picking up or grasping a fresh part at the beginning of a cycle of work is a good point at which to start record.
5. Care must be taken while observing and recording. No activities should be left otherwise it will affect the whole study. Also, avoid combining operations and transportations or positioning, unless they actually occur at the same time. (Refer Fig. 41.7 and 41.8; page no. 709 and 710)

Multiple Activity Chart. A multiple activity chart is a chart in which the activities of more than one item (worker, machine or equipment) are recorded on a common time scale to show their inter-relationship.

By using separate vertical columns to represent the activities of different operators or machines on a common time scale, the chart shows very clearly the period of idleness on the part of any items during the process. A study of the chart often makes it possible to rearrange these activities so that ineffective time is reduced.

Objectives of multiple activity chart :

(*i*) To detect the period of idleness on the part of men and machines.
(*ii*) To determine the number of machines which an operator should be able to look after.
(*iii*) In organising teams of workers on mass production work.
(*iv*) To determine number of workers necessary to perform a job involving team work.

In short multiple activity chart should be used where a process involves a co-ordination of various activities.

A multiple activity chart consists of a series of columns drawn against a common time scale, which starts with zero and terminates at cycle time of the job. The task to be recorded is broken into smaller activities and time for each activity is measured with the help of either a wrist watch or a stop watch.

The activities and their times so observed are then recorded in an appropriate column (*i.e.* activities performed by the man are entered into man column and those performed by the machine are shown in the machine column).

Only two symbols are used in multiple activity chart, these are :

Working Idle

one representing working and other representing idle.

Man and Machine Chart.

The most common use of multiple activity chart is a man and machine chart. In this chart the activities of man and machine are recorded on a common time scale. An operator and the machine always works intermittently i.e. when the machine is idle the operator may be busy in loading the machine or in removing the finished work.

Study of this chart shows the idle time of the man and machine ; it is always desirable to reduce such idle time, this can be done by :

1. Rearranging the activities in relation to each other or changing the sequence of the work elements in a way which will minimize the idle time on the part of the man or the machine or both.
2. Assign additional manpower to the machine so as to minimize the idle time on the part of the machine.
3. Assign some other task to the operator such as inspection, assembly or attending another machine which he can perform during his idle time. (Refer Figs. 41.9 and 41.10 page nos. 711 and 712)

Diagrams. Every business activity involves movement of men and materials from one location to another. Some of these movements can possibly be avoided by rearrangement of the facilities within the plant, by effecting changes in the sequence of activities. The elimination of some of the movement results in substantial saving in the labour cost as well as in the efforts required to carry out the job. Therefore, recording of movements can serve a valuable guide for improving existing layouts.

Operation process chart indicates only the sequence of activities but do not show movements while the flow process chart records the movements but do not provide a visual picture. The problems concerning movements can be better visualised by using diagrams.

The diagrams are of two types :

(i) Flow diagrams (ii) String diagrams

Diagrams highlight unnecessary long travels, cross traffics and obstacles. They are valuable aids to supplement information recorded on the charts.

Diagrams are useful to :

(*i*) study the different plant layouts and thereby select the most optimum layout.
(*ii*) study the extent of traffic over the different routes of the plant.
(*iii*) identify extent of back-tracking, cross traffic and obstacles encountered during movement of materials.
(*iv*) study the activity relationship between departments/sections/work centres.

Flow Diagrams. Flow process chart only shows the sequence of various activities necessary for performing the specified work. It does not show clearly the path of movement of men and materials from one location to another. The path of movement (*i.e.* movement between two locations and the number of times a movement is repeated) can be better visualized by flow diagrams, string diagrams or models.

The flow diagram is used to supplement the flow process chart. It is a plan of work area drawn with a suitable scale. It shows the relative position of productive machinery, storage area, gang ways etc. and the path followed by men or materials is marked on to flow diagram. All routes followed by different items are shown by joining the symbols with straight lines.

Steps in drawing a flow diagram :

1. Draw to scale the plan of the work area.
2. Mark the relative positions of machine tools, benches, store, racks, inspection booths, etc.

(*Contd. on Page 713*)

METHOD STUDY
LEFT AND RIGHT HAND CHART

Job. Assemble two washers and nut to bolt.
Chart begins. Hand empty material in boxes.
Part No. .....
Chart ends. Completed assembly aside to box.
Operation No. .....
Method. Present/proposed.

Charted by

Work Place Layout

LEFTHAND DESCRIPTION	SYMBOL	SYMBOL	RIGHTHAND DESCRIPTION
To bolt			To first washer
Pick up bolt	1	1	Pick up washer
To Position 1			To Position
		2	Assemble to bolt
			To second washer
		3	Pick up washer
		4	To Position
	4	4	Assemble to bolt
		5	To nut
		5	Pick up nut
To Box		6	To Position
Aside to box	2	6	Assemble to bolt
To bolt		1	Delay
			To first washer

Summary

Left Hand				Right Hand		
Symbol	Freq.	Time	Dist.	Freq.	Time	Dist.
○						
□						
⇨						
D						
▽						

Fig. 41.7. Two-handed process chart assembly of two washers and nut to bolt.

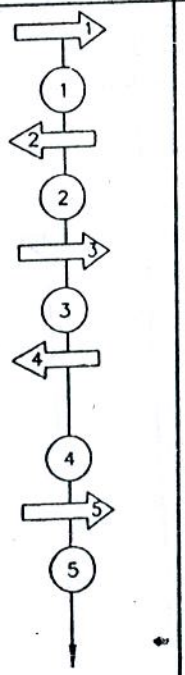
LEFT HAND AND RIGHT HAND CHART

Activity. Signing a letter.

Activity begins. Left hand ready to move to letter.

Charted by : . . . . . .

Activity ends. Letter kept aside in out tray method.

LEFT HAND DESCRIPTION	SYMBOL	SYMBOL	RIGHT HAND DESCRIPTION
To letter			Reach for pen
Grasp			Grasp pen
To position			Carry pen to paper
Hold letter			Sign the letter
			Return pen to holder
			Release pen in holder
			Move hand back to letter
			Grasp letter
			To out tray
			Release letter in out tray

Summary

Left Hand				Right Hand		
Symbol	Freq.	Time	Dist.	Freq.	Time	Dist.
○						
□						
⇨						
D						
▽						

Fig. 41.8. Two-handed process chart of signing a letter.

MULTIPLE ACTIVITY CHART
(Present Method)

Chart No..... Sheet No..... Deptt.....
Material. B-201 casting Job. Making a slot on the casting
Machine. Slotter Operation. XYZ
Charted By..... Date.....

Time (min)	MAN			MACHINE	Time (min)
0.2	Removes finished casting cleans with compressed air			IDLE	0.2
0.4	Gauges depth of slot on surface plate			IDLE	0.4
0.6	Breaks sharp edges with file cleans with compressed air			IDLE	0.6
0.8	Places in a box obtains new casting			IDLE	0.8
1.0	Cleans machine with compressed air			IDLE	1.0
1.2	Locates casting in fixture, starts machine and automatic feed			IDLE	1.2
1.4	IDLE			Cutting slot	1.4
1.6	IDLE			Cutting slot	1.6
1.8	IDLE			Cutting slot	1.8
2.0	IDLE			Cutting slot	2.0

SUMMARY

Cycle Time. 2 Min.
Working time :
(a) Man : 1.2 min.
(b) Machine : 0.8 min.
Idle time :
(a) Man : 0.8 min.
(b) Machine : 1.2 min.

Utilization
(a) Man : 60%
(b) Machine : 40%

Fig. 41.9. Multiple activity chart.

MULTIPLE ACTIVITY CHART
(Improved method)

Time (min)	MAN			MACHINE	Time (min)
0.2	Removes finished casting cleans with compressed air			IDLE	0.2
0.4	Cleans machine with compressed air			IDLE	0.4
0.6	Locates a new casting in a fixture, start machine and auto, feed			IDLE	0.6
0.8	Breaks sharp edges with file, cleans with compressed air			Cutting slot	0.8
1.0	Gauges depth of slot on surface plate			Cutting slot	1.0
1.2	Places casting in a box, picks up new casting and plate by machine			Cutting slot	1.2
1.4	IDLE			Cutting slot	1.4

SUMMARY

Cycle time : 1.4 min.

Working time :

Man : 1.2 min

Machine : 0.8 min

Utilization : Man : 85.7%

Machine : 57%

Idle time

Man : 0.2 min

Machine : 0.6 min

Fig. 41.10. Multiple Activity Chart (Improved Method)

3. From the different observations, draw the actual movements (paths) of the material or the worker on the diagram and indicate the direction of movement.

4. Each movement is serially numbered and indicated by an arrow for its direction.

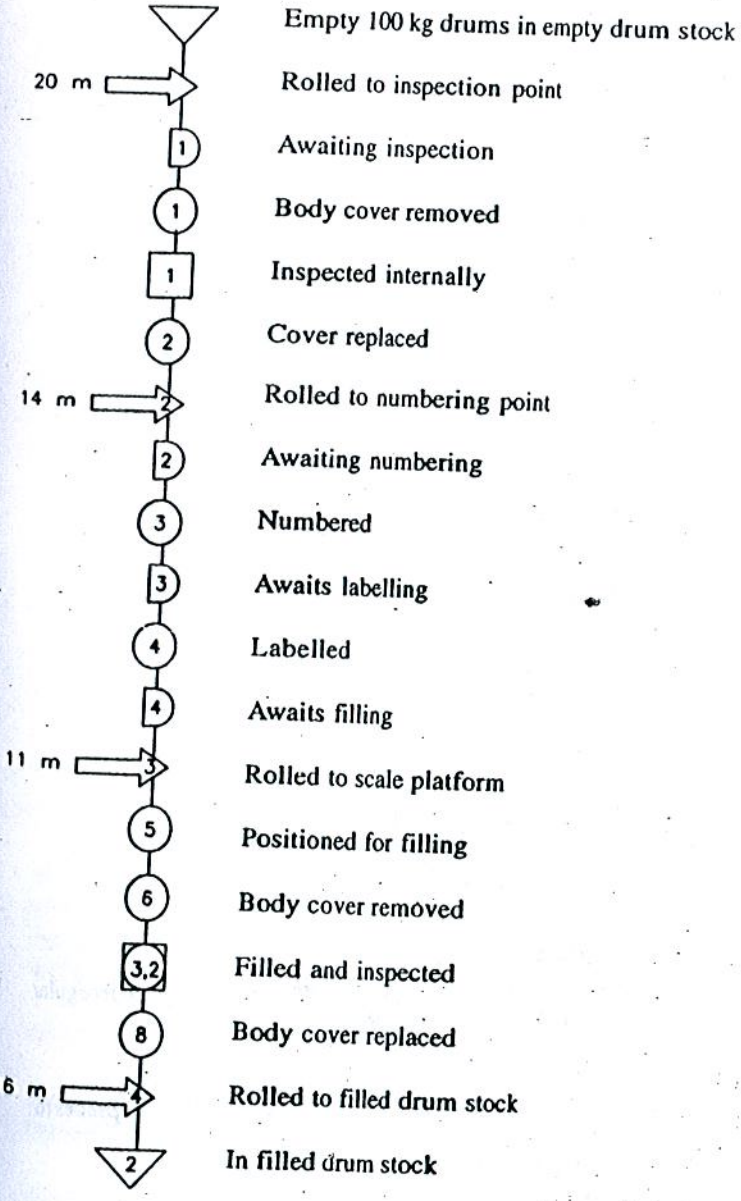
5. Different colours are used to identify different types of movements e.g. worker with empty trolley, worker with loaded trolley etc.

A study of the flow diagram, along with the flow process chart, will trace out the undesirable characteristics of the layout which are responsible for increased transportation and delays. The flow diagram also shows the nature of back tracking involved which could be avoided by suitable changes in the layout. Therefore, flow diagrams are used in solving the plant layout problems and to demonstrate effectively the proposed movements both to management and workers.

The following example illustrates the use of flow diagram along with a flow process chart.

Flow Process Chart (Material Type)

Job. Inspection, numbering and filling of 100 kg drums.
Method : Present method Charted by
Chart begins : Empty 100 kg drums in stock.
Chart ends : Filled 100 kg drums in stock.



Summary :

Operations	–	8
Inspections	–	2
Transports	–	4 - 61 mtrs.
Delays	–	4
Storages	–	2

Flow Diagram :

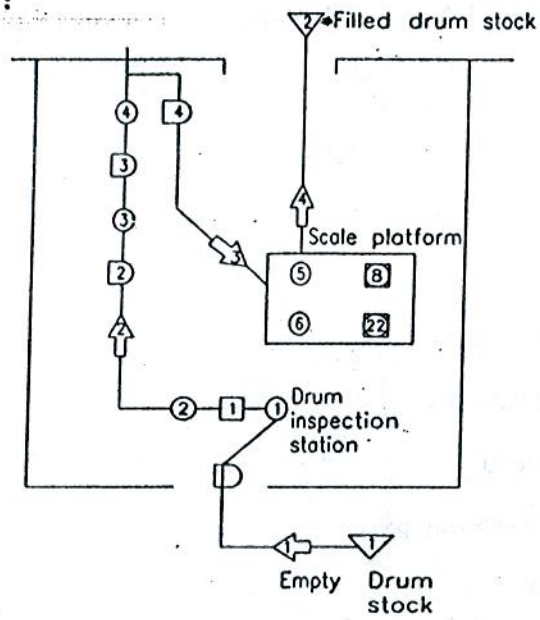


Fig. 41.11. Flow diagram.

Three-dimensional flow diagram can also be drawn as shown in Fig. 41.12.

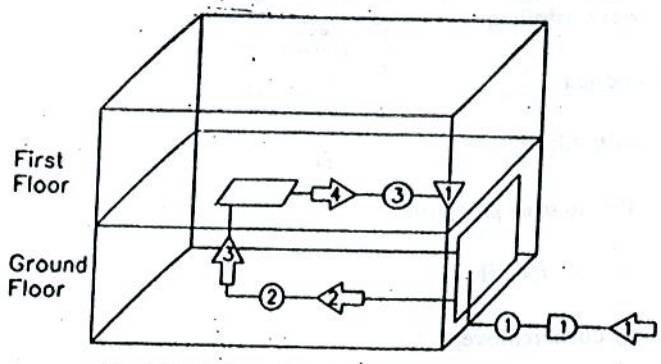


Fig. 41.12. Three-dimensional flow diagram.

String Diagrams. There are many industrial activities in which the workers are moving at irregular intervals between a number of points in a working area, with or without material.

The examples are :

(*a*) An operator is looking after more than one machine.

(*b*) Workers are moving material from a common location to different places or from different places to a common place.

(*c*) In restaurants where different persons are serving different tables.

(*d*) When a team of workers is working at a place.

(*e*) Comparing the relative values of different layouts.

Under such conditions a string diagram is the most useful technique for recording and examining the activities.

"The string diagram is a scale plan or model on which a thread is used to trace and measure the path of workers, material or equipment during a specified sequence of events".

Construction of string diagram :

(1) A layout of the work area is drawn to scale. Positions of machines, benches, stores etc. are drawn into scale on the workplace layout, together with such doorways, pillars and portions as are likely to affect paths of movements.

(2) The completed plan is then attached to a soft board and pins are driven into it firmly at every stopping point, the heads being allowed to stand well clear of the surface (by about 1 cm). Pins should also be driven in at all the turning points on the route.

(3) A measured length of thread is then taken and tied around the pin at the starting point of the movements.

(4) Each movement between the working places is indicated by laying the thread around the corresponding pins driven on the layout.

Repetitive movements are indicated by laying the thread in layers around the pins in the vertical plane.

(5) The distance covered by the object is determined by subtracting the left over length of the thread from its original length.

The result is an over-all picture of the paths of movements of the operators, those which are most frequently traversed being covered with the greatest number of strings. If two or more workers are studied over the same working area, different coloured threads may be used to distinguish between their movements.

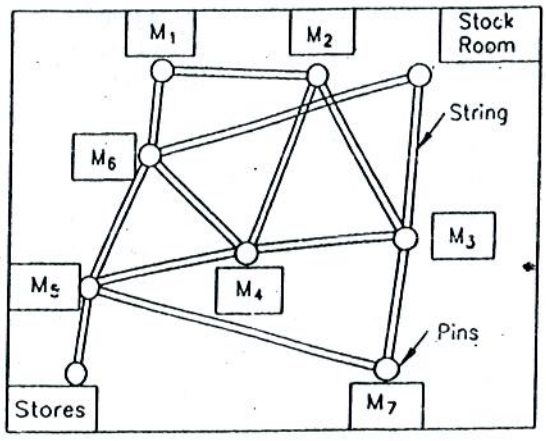


Fig. 41.13. String diagram.

Travel Charts. Though the string diagram is very effective way of recording the movements of the workers or equipment, the preparation of string diagram takes a long time. Secondly, when many complex movements along complex paths are involved, the string diagram becomes complicated.

Therefore, when the movement patterns are complex, the travel chart is a quicker and more manageable recording technique.

A travel chart is a tabular record for presenting quantitative data about the movement of workers, materials or equipments between any number of places over a given period of time.

The travel chart is always a square, having number of small squares within it. Each small square represents a work station. In the following example, there are eight small squares across,

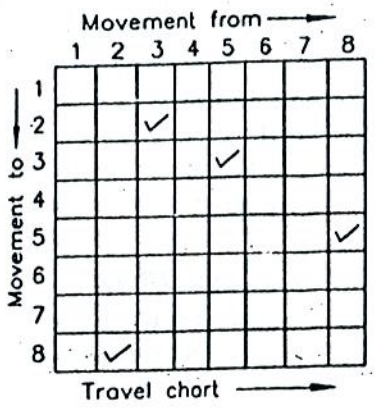


Fig. 41.14. Travel chart.

numbered 1 to 8 from left to right, and eight small squares down, again numbered 1 to 8 going down.

Thus for eight work stations the travel chart contains a total of $8 \times 8 = 64$ small squares. The squares from left to right along the top of the chart represent the places from where movement or travel takes place. The square down the left hand edge represents the stations to which the movements are made.

For example, consider a movement from the station 5 to station 3. To record this select the square 5 on the top of the chart, move down the column below this until the square opposite 3 on left hand edge is reached, and record the movement by a tick mark in that square (at the intersection of the column - 5 and the row 3). Suppose that the movement takes place along the route 5 to 3 to 2 to 8 and back to 5. The journey from 5 to 3 will be marked by a tick as described above. To record the movement from 3 to 2, select a square 3, move down the column below this until the square opposite 2 to the left hand edge is reached, record the movement by a tick mark there. To the top again select square 2, down from these to the opposite row '8' mark another tick mark for that movement. Finally make a tick mark at the intersection of column 8 and the row 5 for recording the final movement.

Models. Sometimes the picture of the existing conditions is not clear by the use of flow process chart or flow diagram. In such cases instead of the scale plans of the shop facilities models are used to provide visual representation of the proposed layout before proceeding with actual rearrangement of the work place.

(1) Two-Dimensional Models. Two-dimensional models i.e. templates are used for various machines, benches and equipments. These templates are made to scale by cutting out pieces of cardboard, plywood or plastic sheet. Different coloured templates may be used to indicate different items of equipment, such as machines, storage racks, benches or material handling equipment. These templates can be placed and attached on the work area drawn to scale. These templates are flexible in use and can be moved on the scaled plan of the work area in order to evaluate various feasible positions for different facilities. While positioning these templates it should be ensured that the gangways are wide enough to allow the free movement of material handling equipment and goods in-process.

Templates offer following advantages over diagrams :

(*i*) The congestion, bottlenecks and backtracking can be better visualised with templates.

(*ii*) They are flexible in use and can be moved on the scaled plan to evaluate various feasible positions for the different facilities.

(*iii*) They are less laborious and save lot of time which otherwise is spent in making drawings for each alternate plant layout arrangement.

Templates, however, have following limitations :

(*i*) Overhead facilities cannot be visualised.

(*ii*) Non-technical persons find it difficult to comprehend the arrangement.

(2) Three-Dimensional Models. Templates though simple and inexpensive do not give real situation effect which is obtained through the use of three-dimensional models or block models. Three-dimensional models are also convenient to study the movements on several floors of a multistorey building. Models represent the real situation since, besides length and width they show the height of the facility also. Three-dimensional models are particularly useful while analysing the material handling problems in chemical industries, floor mills etc. where the material moves upwards and downwards. They are used for demonstrating the layout to the visitors and trainees.

41.5. CRITICAL EXAMINATION

Critical examination is motive force to develop a new method within the limits. It is a questioning technique having a set of questions. The success of work study lies in making a critical examination which has six honest servants i.e. What, Why, How, When, Where and Who. The governing factors can be purpose, means, sequence, place and person.

All the questions can be divided into three categories :

(1)	Primary questions	Deal with facts and reasons.
(2)	Secondary questions	Deal with finding out the alternatives.
(3)	Final questions	Deal with the implication of different alternatives, and select few alternatives for development.

The Primary Questions :

Questioning sequence used follows a well established pattern which examines :

the	PURPOSE	for which	
the	PLACE	at which	
the	SEQUENCE	in which	the activities are
the	PERSON	by whom	undertaken
the	MEANS	by which	
		ELIMINATING	
		COMBINING	
with a view to		REARRANGING	those activities
		or	
		SIMPLIFYING	

The basic objective of primary questions is to find out the facts and reasons.

In the first stage of the questioning technique, the purpose, place, sequence, person, means of every activity is recorded systematically, queried and a reason for each reply is sought.

The primary questions therefore are :

PURPOSE	What is actually done ? Why is the activity necessary at all ?	Eliminate unnecessary parts of the job.
PLACE	Where is it being done ? Why is it done at that particular place ?	Combine wherever possible OR
SEQUENCE	When is it done ? Why is it done at that particular time ?	Rearrange the sequence of operations for more effective results.
PERSON	Who is doing it ? Why is it done by that particular person.	
MEANS	How is it being done ? Why is it being done in that particular way ?	Simplify the operation.

Secondary Questions :

It is the second stage of the questioning technique. During this stage the answers to the primary questions are subjected to further query to determine whether possible alternatives of place, sequence, persons and or means are preferable as a means of improvement over the existing method.

Combining the two primary questions with the two secondary questions under each head. Purpose, place etc. yields the following list, which sets out the questioning technique in full.

PURPOSE	What is done ? Why is it done ?
	What else might be done ?
	What should be done ?
PLACE	Where is it done ? Why is it done there ?
	Where else might it be done ?
	Where should it be done ?
SEQUENCE	When is it done ? Why is it done at that time ?
	When might it be done ? When should it be done ?
PERSON	Who does it ? Why does that person do it ?
	Who else might do it ? Who should do it ?
MEANS	How is it done ? Why is it done that way ?
	How else might it be done ?
	How should it be done ?

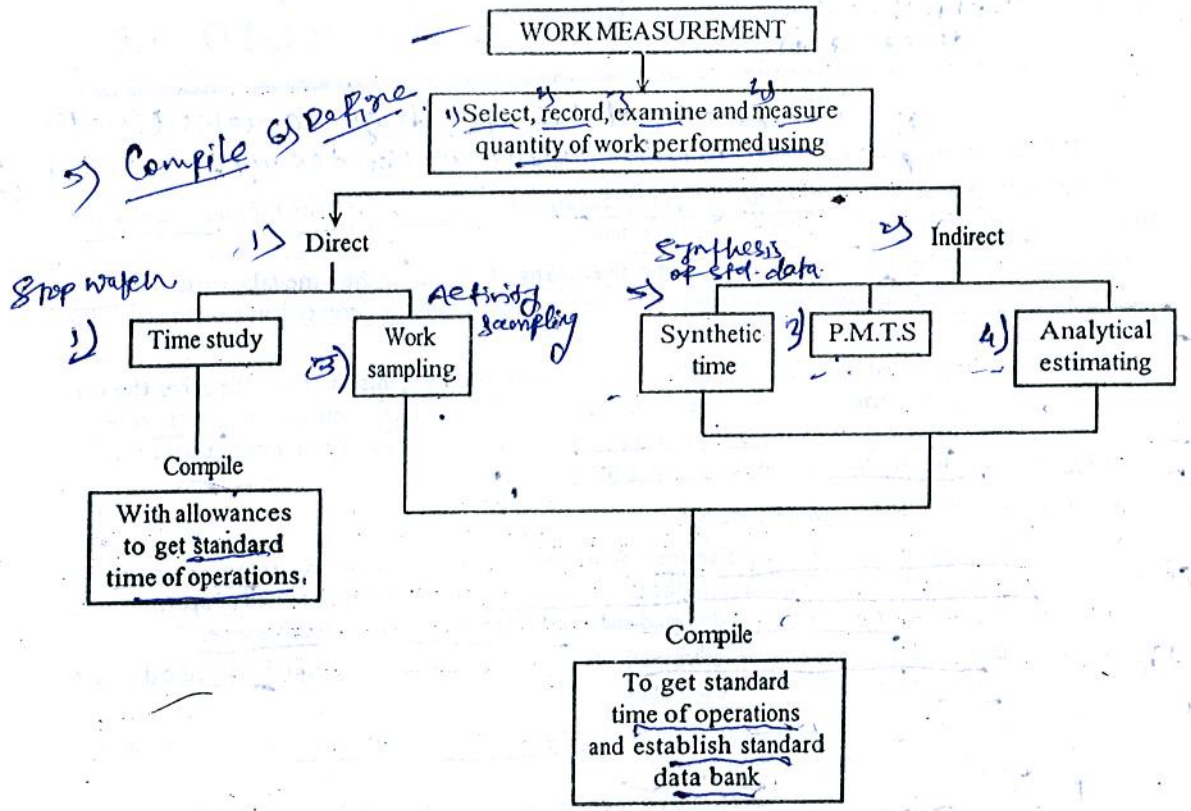


Fig. 42.1. Work measurement.

42.3. THE TECHNIQUES OF WORK MEASUREMENT

The following are the principle techniques by which work measurement is carried out :

1. Stop watch time study.
2. Predetermined motion time systems (P.M.T.S.).
3. Activity sampling or work sampling.
4. Analytical estimating.
5. Synthesis from standard data.

Basic procedure for work measurement :

The following steps are necessary for carrying out the work measurement systematically.

1. Select. The work to be studied and determine the objectives of the study.

2. Record. All the relevant data relating to circumstances in which the work is being done, the methods to be used. Break down the job into its elements.

3. Examine. The recorded data and the detailed breakdown critically to ensure that most effective method and motions are being used and that unproductive elements are separated from productive elements.

4. Measure. The time required to complete each element using the appropriate work measurement techniques and calculate the time required to complete the work cycle which is known as basic time.

5. Compile. The standard time for the operation or work cycle. In case of stop-watch time study the various allowances to cover relaxation, personal needs etc. are added to the basic time to estimate the standard time.

6. Define. Precisely the series of activities and method of operation for which the time has been compiled and issue the time standards for the activities and methods specified.

42.4. TIME STUDY

Definition. Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance.

Time Study Equipment. The equipment required for time study consists of :

(1) Stop Watch ;
(2) Time Study board ;
(3) Time Study forms ;

In addition to this, in the study office there should be :

(4) A small calculator ;
(5) A reliable clock, with a seconds hand ;
(6) Measuring instruments such as a tape measure, steel rule, micrometer, spring balance etc.

The Stop Watch. The two types of stop watches commonly used for time study are :

(1) Flyback decimal minute stop watch.
(2) Non-flyback stop watch.

Flyback decimal minute stop watch is most commonly used for time study.

In this type of watch the movement is started and stopped by moving the slide A, forward and backward respectively. One complete revolution of the large hand represents 1 minute and since the dial is divided into 100 parts, reading to within 0.01 minute can be obtained. Every time the large hand makes one revolution, the small hand will register 1 minute and is able to register up to 30 minutes.

If the analyst stops the watch at any point by moving the slide backward, he can return both hands to zero by pressing the winding knob B. So long as the slide remains in the backward position, the hands will not rotate.

Now, if the side slide is in the forward position, which means that the hands are rotating pressing the winding knob will also return the hands back to zero. However, as soon as the winding knob is released, the hands will begin rotating again. This is because the watch had not been stopped by moving the side slide backward.

Non-fly back type stop watch is controlled by pressure on the top of winding knob. The first pressure starts the watch ; the second pressure stops it ; the third pressure returns the hands to zero.

This watch is suitable only for cumulative timings.

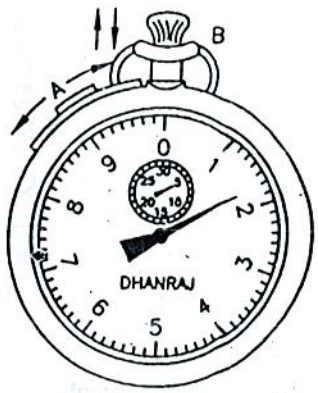


Fig. 42.2. Decimal stop-watch for time study.

Time Study Board. It is simply a flat board, usually made of plywood, hard board or a plastic sheet. It is provided with the fittings to hold the stop watch and a strong spring clip to hold the time study form. The watch is held at a convenient position so that it can be operated by the left hand. The time study board is rigid and larger than the largest form likely to be used. The overall size of the board should be such that not too much static strain gets developed in the body support system that is required to keep the board in proper position all throughout the observation phase. A study board which is too long or too short for a study man's arm soon becomes tiresome to use. Most study men therefore prefer to have their own individual study board which is suitable for their arm length.

Time Study Forms. Printed or cyclostyled forms are used for recording the observations during time study. It ensures that time studies are made in a standard manner and that no essential data are omitted. These forms are attached to the time study board by means of the clip provided.

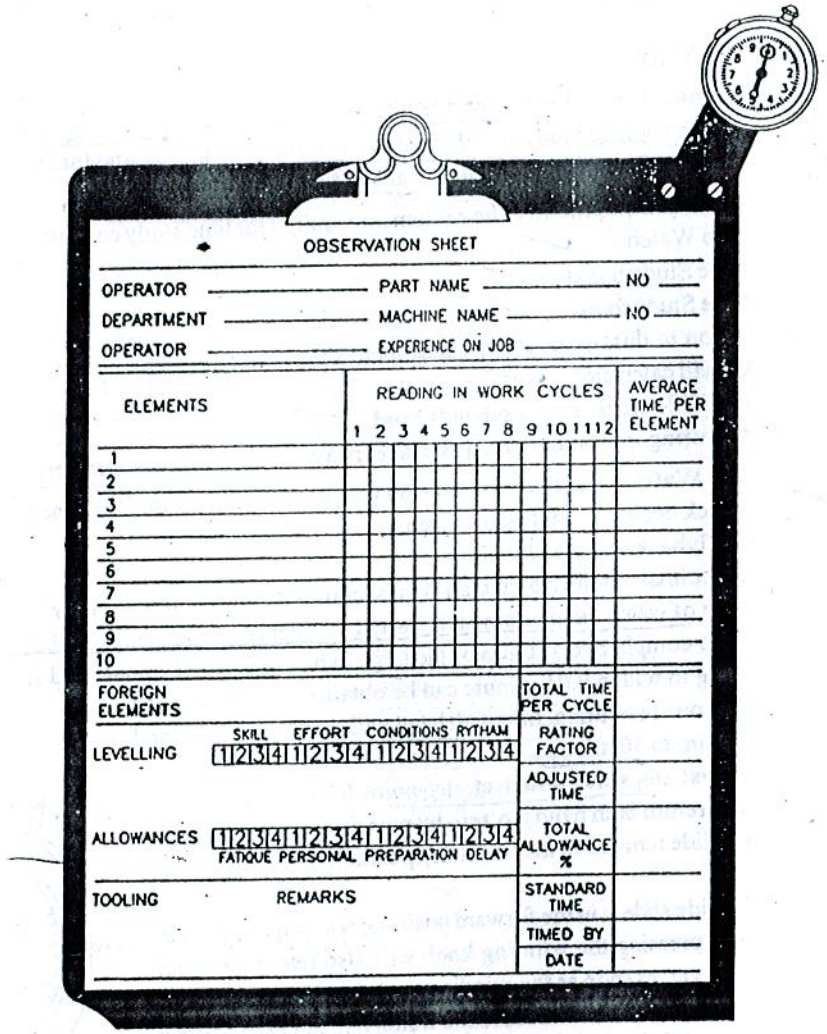


Fig. 42.3. Stop watch and observation sheet on a clip board.

All the essential information about the time study is recorded on the time study forms. The reverse side can be used to note the other details of the method such as description of the method, sketch of the work place layout etc. Such a recording must be made by pencils so that the readings can be rubbed if necessary. Two types of forms are used : those used to record the observation with such overall size that they can be fitted on the time study board conveniently ; and those which are to be used in the time study office after the observations have been recorded in the first type of forms.

The forms used for recording the observation are also of two types :

(*i*) General purpose time study form (*ii*) Short cycle study form as shown in Figs. 42.4 and 42.5.

Forms used in the Time study office :

Working Sheet. This sheet is used for analysing the data obtained during the study to derive representative time for the elemental operations identified.

Study summary sheet. This sheet is used for recording the selected or derived times for the elemental activities along with their frequencies of occurrence. This summarises the information recorded during the course of study. The headings include the relevant details recorded in the time study top sheet. The summary is placed on top of the time study sheets providing the data base which are of the same size. A typical layout of such sheet is shown in Fig. 42.4.

47 Ergonomics

47.1. CONCEPT OF ERGONOMICS

The concept of ergonomics helps to study the effect of health and safety *i.e.* working environment on productivity. Bad working conditions affect the productivity adversely, while good working conditions make the workers take more interest in their job. And the workers interest in the job to a greater extent depends on how comfortable and safe the workplace is. A number of factors need to be considered while designing a workplace and the science which considers these factors is called Ergonomics. Thus, Ergonomics is the science which deals with the relationship between man and his working environment.

It aims to improve human well being through attainment of optimal working conditions and by the most suitable use of his physical characteristics and physiological and psychological capabilities. It thus improves overall system performance by optimising human-system compatibility. It takes care of the factors governing the physical and mental strains caused to the worker while carrying out the work.

Ergonomics combines the knowledge of a physiologist, psychologist, anatomist, engineer and anthropologist. It is also called as 'Human Engineering' in U.S.A.

Definitions of Ergonomics :

- The word Ergonomics is derived from the Greek words 'Ergo' which means work, and 'Nomos' means 'Natural Laws'. Therefore, ergonomics means laws of work.
  And the subject dealing with the human aspects of design for a given environmental conditions is known as 'Ergonomic Design'.
- Thus ergonomics can also be defined as the study of relations between man and his environment, occupation, equipment and particularly, the applications of anatomical, physiological, psychological knowledge to solve the problems arising between machine and machine interface.
- Ergonomics is the science of work which deals with the relationship between man and his working environment. It implies 'Fitting the job to the worker'
- Ergonomics is the process of designing or arranging work places, products and systems so that they fit the people who use them.
- Ergonomics is defined by I.L.O. as the application of human biological sciences in conjunction with engineering sciences to the worker and his working environment so as to obtain maximum satisfaction for the worker which, at the same time, enhances productivity.

Thus ergonomics is a multi-disciplinary science comprising subjects like anatomy, psychology, physiology, sociology, engineering, anthropology, physics and medicine :

- Ergonomics is the study of human abilities and characteristics, which affect the design of equipment, systems and jobs.
- According to International Ergonomics Association Executive Council, "Ergonomics is the scientific discipline concerned with the understanding of the interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance".

47.2. OBJECTIVES OF ERGONOMICS

The basic objectives of ergonomics are :

1. Ergonomics aims to improve human well-being and overall system performance by optimising the integration of man and machine.

2. It takes care of the factors governing the physical and mental strains (fatigue), so as to obtain maximum satisfaction for the worker which at the same time enhances productivity.
3. It attempts to minimize the risk of injury, illness, accidents and errors without compromising productivity.
4. To improve the design of machine at the initial design stage or later in the modification of an existing product.
5. To enhance the man-machine relationship.

Thus the task of ergonomics involves :

(*a*) To develop the most comfortable conditions for the worker as regards lighting, climate, ventilation and noise level.

(*b*) To reduce the physical work load (in particular) in hot environments.

(*c*) To improve working postures and reduce the effort of certain movements.

(*d*) To facilitate psycho-sensorial functions in reading instrument displays.

(*e*) To make the handling of machine levers and controls easier.

(*f*) To make better use of spontaneous and stero-typed reflexes.

(*g*) To avoid unnecessary information recall efforts and so on.

Advantages of Ergonomics :

1. Higher productivity.
2. More human comfort, less fatigue to the operator.
3. Better design of machines.
4. Increased safety (reduction of accidents).
5. Better integration of man-machine system.
6. Reduced labour turnover.

47.3. HISTORICAL BACKGROUND

As already stated, the word Ergonomics was derived from the Greek words : 'Ergo' meaning work and 'Nomos' meaning the natural law. The name ergonomics was officially proposed in 1949 by a group of British Scientists who were concerned with the efficient use of complex military equipment during the Second World War.

Though 'ergonomics', 'human engineering' and 'bio-technics' (still another name of this study) may be comparatively new words, the whole subject stretches back through history. George Bauer studied the ailments and difficulties of silver miners in the early part of sixteenth century. At the turn of seventeenth century Ramazzini studied working conditions and occupational diseases in a variety of trades. In Britain the Ergonomic Society was formed in 1952 with people from psychology, biology, physiology and design. The Human Factors Society was formed in 1957 in United States. US military emphasized 'human factors engineering' with concentration on human engineering and engineering psychology. US efforts also focussed on the role of an individual within a complex system.

With the increasing awareness of ergonomics, the emphasis shifted from the generally accepted policy of 'fitting man to his machine by means of selection and training' to 'fitting the machine to the majority of men who work with them'. The modern approach, however, is of compromising nature : 'fit man and machine together'. After the war, the scope of ergonomics has been broadened beyond the mere protection of worker's physical integrity and aim at ensuring his well being through attainment of optimal working conditions and by the most suitable use of his physical characteristics and physiological and psychologicl capabilities to improve overall system performance.

47.4. RELATED SCIENCES OF ERGONOMICS

The study of man at work calls for the knowledge of anthropology, physiology and psychology. When considering machines, the investigator must have the knowldege of engineering sciences. The role of each subject is as follows :

1. Anthropology. It is the study of the variation of human characteristics such as height, weight, reach, ratio of leg length to shoulder length etc. Such variations between the individuals and sexes are noted and the mean value and spread is determined. The data is useful for determining the boundaries of the work-place, heights and shapes of the seats and work tables to suit human body measurements. The data is also useful for designing handles, levers etc. so that they are easy to reach and operate.

2. Physiology. Physiology is concerned with the determination of :

(*a*) the effect of stress and strains caused by environmental factors like light, heat, noise, humidity and atmospheric conditions etc. on human body and the extent to which it can tolerate.

(*b*) the human stamina ; and

(*c*) the speed, accuracy and force with which body movements can be carried out.

Studies have revealed that the knowledge of speed, accuracy and force of movement of each body member helps jobs or machines to be designed so that heavy work is done by the big muscles, and light work by the small ones, thus reducing the number of muscle groups involved in any work situation to a minimum.

The knowledge of human stamina is useful in the work organisation, for instance, in determining the work and rest schedules.

Studies have shown that poor ventilation, low illumination, high temperature and unbearable noise levels in industry result in loss of efficiency, discontent, fatigue and increased rate of accident and sickness. It can also affect labour supply, since workers nowadays prefer to work in pleasent environment. Thus knowledge of what constitutes a good working environment is important for the design of working conditions conducive to efficient working.

Physiology and Anotomy are inter-related terms as anotomy deals with the study of internal details of human body.

3. Psychology. This is the study concerned with human behaviour and human reactions under various working conditions and under the influence of mental strain. Ergonomic designs are aimed at eliminating human drudgery and minimising the effect of job factors which make the job uncomfortable. In the language of ergonomics the factors which make the job uncomfortable are called 'stressors' and the effect of stressors on human body is called strain. Strain can be either physiological or psychological or combination of them.

47.5. MAN-MACHINE SYSTEM-INTERFACES

A man-machine system (MMS) may be defined as a combination of man (or men) and some machine interacting to bring about the desired output from given inputs.

Both 'man' and 'machine' are used in a broader sense : "man" includes woman, and the 'machine' is any physical equipment, device, facility, tools, or thing people use in carrying out any activity. All MMS work is in some kind of physical environment (work space and ambient environment). Examples of simple MMS are : a man with a hammer ; a typist with a typewriter.

Classification of Man-Machine System

Man-machine system can be classified as :

1. Closed Loop System.
2. Open Loop System.

A closed loop system is continuous one in which some process is performed that requires continuous control and feedback for its success. The feedback provides information about any error that should be taken into account in the continuing control process.

Fig. 47.1 shows a closed loop system. Examples of close loop system are : A driver driving a car, an operator working on lathe etc.

An open loop system is one which, when started, needs no further control or atleast cannot be further controlled. There is no feedback in open loop system.

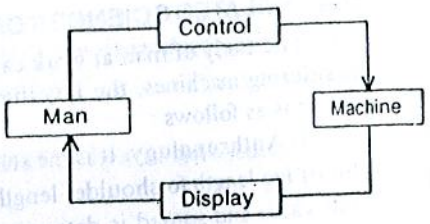


Fig. 47.1. Man-machine system.

Man-machine systems can also be classified by the mode of operation of the system as follows :

1. Manual system ;
2. Mechanical system, and
3. Automatic system.

Manual System. In manual system all the operations are done manually by using hand tools and the operations are controlled by the operator.

Mechanical System. Mechanical system consists of man with a power-driven machine. The machine is designed to operate on electric power (or some other source but not manually) and perform its function with little variation. Operator controls the operations by using controlling devices such as levers, handles, push buttons etc. Examples : turner plus lathe, driver plus car, operator driving railway engine etc.

Automatic System. Automatic systems consists of machines which are expected to perform all operational functions, that is sensing, information processing, decision making, and action. An automatic telephone exchange will fall under this type of system. A fully automatic system will be programmed that appropriate actions will automatically be taken by the machine itself. In other words, in automatic system all operations are carried automatically and operator is required only for installation, programming and maintenance of the system.

It may be noted that the distinctions between manual, mechanical and automatic systems are not very clear-cut. Within any given system, different sub-systemes can vary in the degree of their manual versus automatic features.

Many ergonomic measures are of a kind that should be introduced at the design stage of a building, appliance or machine, or when the equipment is being installed, since subsequent modifications are generally less effective and much more expensive.

A machine user should incorporate the application of specific ergonomic standards in the clauses of his contract with the machine manufacturer. The contract should cover safety colours, warning lights and controls that have already been standardized by the international organisation and the International Electrochemical Commission in particularly display panels and dials. In addition, attention should be given not only to items affecting production but also to critical maintenance features.

47.6. IMPORTANT ASPECTS OF MAN-MACHINE SYSTEM

The important aspects of a man-machine system are :

1. Design of Visual Display.
2. Design of Work Posture.
3. Design of Control.
4. Environmental and Working Conditions.

1. Design of Visual Display. Display is a device which provides information about the state of a system to the observer. The information that can be presented by displays may be static or dynamic. The dynamic information changes with time, *e.g.* Traffic Signal. Further, it may be any of the following types :

1. **Quantitative.** This type of information gives quantitative value of some variable, such as pressure, current, voltage, discharge etc.

2. **Qualitative.** The qualitative information is one which concerns the rate of change, direction of change, trend or other aspects of some changable variable, *e.g.* Dial indicator, pressure gauge fitted on a steam chamber etc.
3. **Status.** The information about the condition or status of a system may be presented by indications of one of the limited number of conditions.

   Examples : On off indication, railway line signal indicating clearance or non-clearance of track.
4. **Warning.** The information indicating the presence or absence of some disastrous condition may be displaced by a visual signal (red light) or an audio one (siren).
5. **Identification.** The information which identifies the presence or absence of specific object, situation or condition which can be displayed in a coded form. For example, a red coloured cylinder may indicate that it contains some inflammable material.
6. **Representational.** The information about the variable may be displayed in a symbolic manner by line diagram, bar chart or position of a pointer on a instrument dial.
7. **Alphanumeric.** Information in coded numerical may be displayed in the forms, such as sign boards, music notes, computer printouts, and classroom instructions etc.

The visual displays are of several forms namely analogue meters, digital meters, indicating devices, graphic displays etc.

Ergonomic Principles Suggest that :

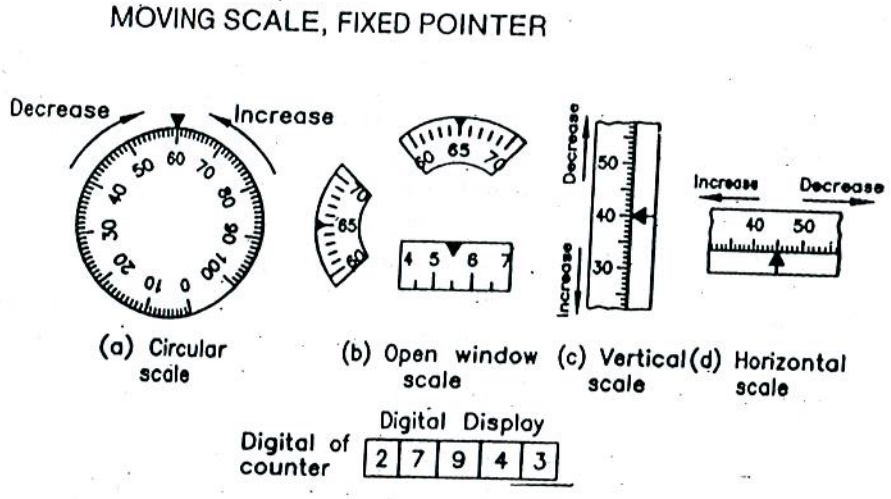
- display should be as simple as possible and it should convey only the essential information.
- visual systems should be preferred over auditory systems in noisy locations.
- monitoring displays must be placed within focal or peripheral limitations.
- glow-in-the dark dials made of non-reflective substance are good for viewing in the nights.
- since the ability to process signals declines with time, short breaks and rotation on the tasks should be used wherever desirable.

Basic types of dynamic quantitative displays :

The three basic types of quantitative displays used for presenting dynamic information are

1. Fixed scale with moving pointer.
2. Fixed pointer with moving scale.
3. Counters or digital displays.

Fig. 47.2 shows some commonly used designs of these three types.



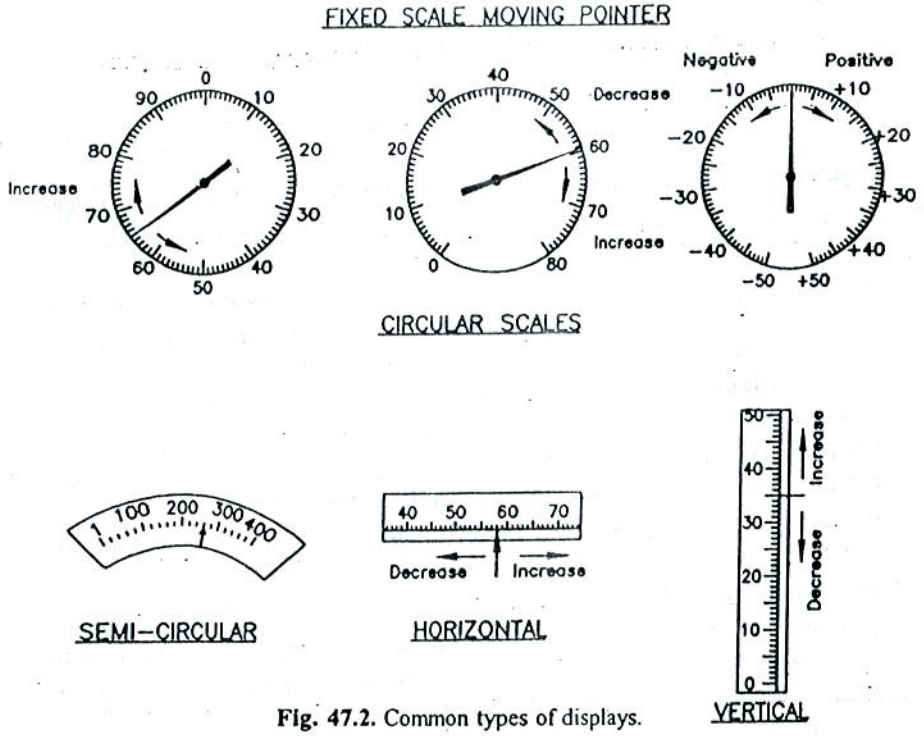


Fig. 47.2. Common types of displays.

A fixed scale moving pointer is the most versatile of the three types. It can be used for both an accurate reading as well as an approximate reading. This type of display can also be used to determine the rate and direction of change of the variable. Fixed scales however cannot be used when the range of values is too large to be shown on the face of a relatively small scale. In such cases, a moving-scale fixed pointer, like horizontal or vertical scale has the practical advantage of occupying a small space, since the scale can be wound around spools behind the panel face with only the appropriate portion of the scale exposed. Moving scale is also preferred when a numerical value must be quickly read and this appears in a window segment of the display.

The digital counter is useful where precise reading of numerical values is required in the shortest possible time. It is best suited for quantitative reading. Digital counters are not useful where variable may change rapidly.

Design of Work Place :

The *work place* is a space in a factory which must accommodate an operator, materials, tools, machines and auxiliary services need to perform a specific task. While planning a workplace, a care should be taken that each area should be planned for optimum efficiency and should fit into the overall flow pattern.

Ideally, a workplace should be custom built for the use of one person whose dimensions are known. For general use, however, a compromise must be made to allow for the varying dimensions of humans. Therefore, a workplace should be so proportioned that it suits a chosen group of people.

Fig. 47.3 shows suggested critical dimensions for a group of males using a seated work place. The Fig. shows the left hand covering the maximum working area and the right hand covering the normal working area. Normal working area is the space within which a seated or standing worker can reach and use tools, materials and equipment when his elbow falls naturally by the side of the body. Maximum working area is the space over which a seated or standing worker has to make full length arm movements (*i.e.* from the shoulder) in order to reach and use tools, materials and equipment.

All tools and materials required must be located within the normal grasp area and as far as possible in front of the operator (within the area shaded) so that they can be seen and reached quickly and easily to save time and energy.

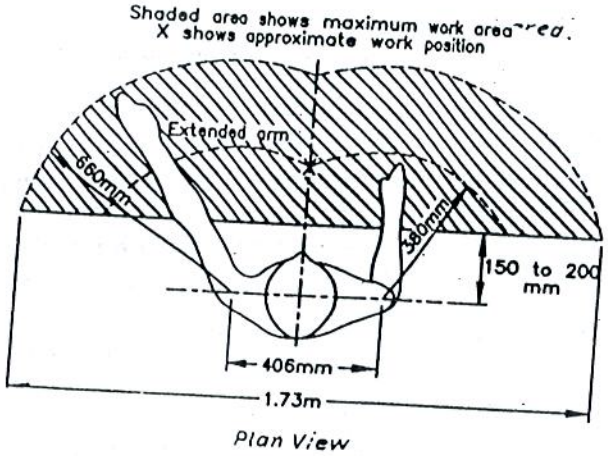


Fig. 47.3. Critical dimensions of a seated person.

Guidelines for Efficient Work Place Design

The following guidelines are useful in designing efficient work place arrangements :

1. Group together components of similar function.
2. Locate critical (or most important) controls in the best locations so that they can be used easily and rapidly.
3. Arrange components in logical sequence as they would mostly be operated or viewed.
4. Arrange most frequently used components in central locations, and those infrequently used in peripheral areas.
5. Arrange controls in the work place giving due considerations to the reaction time, accuracy of movement, and the amount of force required for their operation.

Where a large number of controls and displays are to be arranged, all these guidelines cannot be expected to meet. Some guidelines may even conflict with another, for example, if components are grouped according to the function they perform, the arrangement may not fullfill sequence-of-use guideline. In such cases, it may be useful to follow the following priority rules :

1. First priority : primary visual task.
2. Second priority : primary controls that interact with primary visual tasks.
3. Third priority : Better control-display relationships, for example, locate controls near associated displays, have movement of control compatible with the movement of display, etc.
4. Fourth priority : Sequential arrangement of elements with respect to their usage.
5. Fift priority : Location of frequently used elements with easy reach.

Work Posture :

The posture that a workman needs to adopt to perform the task is an important consideration in the design of the work place. Incorrect posture can cause strain in back, waist, legs and hands. A lot of data is available on ergonomic design of the seats—type of seat, seat height, back support, arm support, foot rests etc.

The general rules to be followed for adopting correct posture are as follows :

— The design of the work place and that of the equipment should be such that the operator can perform the task in a varied posture. A design that forces the body member to take a particular posture over an extended period should be avoided.

— The working posture must be sitting for foot pedal operations.

40 Productivity

40.1. WHAT IS PRODUCTIVITY ?

A farmer produces from one hectare of land 10 more bags of wheat during a season, using improved farming technique and better quality seeds.

A tailor is able to make 10 shirts from 13 metres cloth, by changing his cutting method, in place of the usual 1.5 metres per shirt he used to take previously.

A machinist is able to produce 30 jobs per day on two machines instead of 20 jobs per day, by attending to one machine only.

A machine tool produces 100 jobs per working day instead of 80 jobs through the use of improved cutting tools.

One common thing that we find in all these situations given above, is the increase in output.

The farmer is able to produce more from the same piece of land without bringing in any additional input. He has only changed his farming technique and used a better quality of seeds. Thus we may say that without any change in input the output from the land has increased. In engineering we call the ratio, as $\frac{\text{output}}{\text{input}}$ as efficiency.

In production system we may call this ratio as the production efficiency or productivity. So, when this ratio increases, there is an increase in productivity.

Therefore, productivity is an efficiency of the production system which is expressed by the ratio between output and input. When the tailor is able to reduce the length of cloth used per shirt by adopting an improved cutting technique, the input (cloth) per shirt reduces while the output (shirts) remains constant. Thus, there is an increase in productivity, in the utilization of the material (cloth).

The machinist was producing 20 jobs per day, while he was working on one machine. It was quite likely that he might have been idle for some time while the machine was on automatic feed. By working on two machines he produces 30 jobs, per day. If we consider the utilization of his working time, we may say that the productivity of the machinist has increased.

Similarly, the productivity of a machine tool increases by using improved cutting tool and also by using improved method of working.

Definitions of productivity

– Productivity is a measure of how much input is required to produce a given output i.e. the ratio $\frac{\text{output}}{\text{input}}$ is called productivity.

– Productivity of a production system is analogous to the efficiency of a machine.

– Productivity can also be defined as human efforts to produce more and more with less and less inputs of resources as a result of which the benefits of production are distributed among maximum number of people.

– European productivity council defines "productivity is an attitude of mind. It is a mentality of progress, of the constant improvement of that which exists. It is the certainty of beings able to do better than yesterday and continuously. It is constant adaptation of the economic and social life to changing conditions. It is the continual effort to apply new techniques and methods. It is the faith in human progress".

– According to Peter Drucker, "Productivity means a balance between all factors of production that will give the maximum output with the smallest effort".

– ILO defines total productivity as the ratio of aggregate output to aggregate input. Partial productivity

is the ratio of the aggregate output to any single input. The definition applies for an enterprise, an industry or an economy as a whole. Examples of partial productivity are labour productivity, capital productivity.

– Productivity implies development of an attitude of mind and constant urge to find better, cheaper, easier, quicker and safer means of doing a job, manufacturing a product and providing services.

When we consider an industry as a whole, the productivity can be expressed in terms of the ratio between the value of the goods and services produced to the value of the resources utilized for this production.

$$\text{Thus, productivity} = \frac{\text{Value of goods and services produced}}{\text{Value of resources utilized for this production}}$$

So, productivity refers to efficient utilization of the resources. The resources utilized for production are :

Land and Building. Land is a convenient location on which the buildings and other facilities necessary for the operation of manufacture are erected.

Materials. Materials that can be converted into products to be sold. They include fuel, chemicals for use in the process of manufacture, packing and other indirect materials etc.

Machines. Plant, equipment and tools necessary to carry out operations of manufacture and the transport of materials, heating, ventilating and power plant ; office equipment and furniture.

Manpower. Men and women to perform the manufacturing operations ; to plan and control, to do clerical work ; to design and to research ; to buy and sell.

The use of all these resources combined together determines the productivity of the enterprises. Since, higher productivity means more output from the same resources, it also means lower money costs and higher net money returns per unit of output.

40.2. PRODUCTIVITY AND PRODUCTION

The concept of productivity and production are totally different. Production refers to absolute output while productivity is a relative term wherein output is always expressed in terms of input. The production may rise without the corresponding rise in the productivity and vice versa. If the input remains the same and the production of output increases there is a rise in productivity.

If the output rises in greater proportion than the increase in input, there is still a proportionate rise in the level of productivity. But if the output rises at slower rate than the input there will be fall in productivity even though there is an increase in production on the whole.

Production, therefore, means the output in terms of money whereas productivity is the efficiency of production system.

40.3. MEASUREMENT OF PRODUCTIVITY

The basic objectives behind productivity measurement are :

(*a*) to study performance of a system overtime.

(*b*) to have relative comparison of different systems for a given level; and

(*c*) to compare the actual productivity of the system with its planned productivity.

The measurement of productivity creates a problem in the following circumstances. When the production system produces different types of output, it is necessary to have a common unit of measurement to arrive at the aggregate output. Similarly, whenever different kinds of input like capital and labour are to be added to arrive at an aggregate input figure, a common unit of measurement is needed for these inputs.

Even for the partial productivity measures involving only one kind of input, problem exists in terms of aggregating over different kinds of the same input. For example, labour as an input may have different categories like skilled, semiskilled, unskilled, that need to be aggregated.

The most common way is to express both outputs and the inputs in monetary terms.

If the outputs and inputs for the period for which productivity is measured, are expressed in rupees, then under certain restrictive assumptions, we can write :

materials and pay for them in scarce foreign currencies. Under either of these conditions the productivity of materials becomes a key factor in economic production or operation.

$$\text{Material productivity} = \frac{\text{Number of units produced}}{\text{Cost of material}}$$

Raw material productivity can be increased by :

1. Proper choice of design.
2. Proper training and motivating of workers by way of better handling of materials and reduction of rejection.
3. Better material planning and control ; use of jigs and fixtures.
4. Waste reduction, scrap control.
5. Proper care of materials in storage.
6. Recycling and reuse of materials.
7. Searching alternative cheaper materials etc.

$$\text{Labour Productivity} = \frac{\text{Aggregate Output}}{\text{Amount of Labour}}$$

Where output can be measured in total quantity produced and labour can be measured in total man hours required to produce that output. Output and labour can also be measured in terms of their value in money units.

$$\text{Thus, Labour Productivity} = \frac{\text{Total Revenue from Production}}{\text{Expenditure on Labour}}$$

The labour productivity can be increased by :

(*i*) Selection of product design and process of manufacture so as to ensure most economical use of labour.
(*ii*) Providing training to use best method of production.
(*iii*) Constantly motivating workers by providing financial and non-financial incentives.
(*iv*) Keeping high morale of employees.
(*v*) Improving working conditions in the plant.
(*vi*) By providing opportunities for self-development.

$$\text{Capital Productivity} = \frac{\text{Turn over}}{\text{Capital employed}}$$

Capital productivity can be improved by :

(*i*) Better utilization of capital resources like land, building, machines.
(*ii*) Careful make or buy decision.
(*iii*) By using modern techniques of production, maintenance, flexible manufacturing system, proper plant layout etc.

$$\text{Machine Productivity} = \frac{\text{Output}}{\text{Actual machine hours utilized}}$$

Machine Productivity can be improved by following :

(*i*) Preventive maintenance.
(*ii*) Use of proper speed, feed, depth of cut etc.
(*iii*) Using method study techniques (using best method).
(*iv*) Use of skilled, properly trained workers.
(*v*) Line balancing etc.

General Measure of Productivity :

$$\text{Aggregate Productivity} = \frac{\text{Output}}{\text{Land + Labour + Material + Capital + Other Inputs}}$$

40.5. IMPORTANCE OF PRODUCTIVITY

The concept of productivity is of great significance for undeveloped and developing countries. In both the cases there are limited resources which should be used to get the maximum output i.e. there should be attempts to perform a job by cheaper, safer and quicker ways. The aim should be optimum use of resources so as to provide maximum satisfaction with minimum efforts and expenditure. Productivity analysis and measures indicate the stages and situations where improvement in the working inputs is possible to increase the output.

The productivity indicators can be used for different purposes, *viz.* comparison of performances for various organisations, to study performance of the organisation overtime, to compare actual productivity with its planned productivity, contribution of different input factors, bargaining with trade unions etc.

Productivity is a key to prosperity. Hence an autonomous organisation was established in India, known as National Productivity Council (NPC). It was established in 1958 and has 5 regional productivity directorates in the country managed by specialists for organising productivity programmes. It has also established 47 local councils at various industrial centres in the country and they work as the spear head of the productivity movement.

To increase productivity, NPC supplies publications, utilities, audio-visual media films, organises exhibitions. In collaboration with local productivity councils and various institutions, it organises and conducts training programmes for various levels of management. It also provides assistance, guidance to industries in other activities and difficulties.

40.6. MEANS OF INCREASING PRODUCTIVITY

Every management tries to improve the productivity. The productivity can be improved broadly by the following two ways :

(1) Increasing the resources and thereby production.

(2) Effective utilisation of resources.

According to the first method if we increase the resources such as labour, machines, materials etc., the productivity may improve but there are limitations to increase the resources as it needs more capital investment. Secondly, after increasing the resources above certain limit, it is possible that the production may rise but in small proportion as compared to increase in input and hence the productivity may decrease.

Whereas second method requires very little capital investment to improve the productivity.

In country like ours, the second method is preferred due to limited capital. The various resources are raw material, capital investment, labour, technological know-how, managerial skill, machines etc. Better utilization of resources means reduction of scrap, and utilizing idle time of men, machines etc.

$$\text{Since, Productivity} = \frac{\text{output}}{\text{input}}$$

As seen from the example discussed earlier, productivity can be increased in three ways :

(1) By increasing the output from the same input.

(2) By reducing the input for the same output.

(3) By a small increase in input, achieving a substantial increase in output.

Thus, the productivity of the enterprise will be increased when :

(1) The quality and quantity of output is increased by better management, by using best possible method determined by method study, while the input remains the same.

(2) The input is reduced by avoiding waste in all forms.

(3) For better utilization of existing resources, a small increase is made in the inputs resulting in a large increase in output. Attempts for improving the productivity of an industrial enterprise will have to be directed towards these three areas.

Role of government, employers and workers for productivity improvement :

To achieve the greatest increase in productivity, action must be taken by all sections of the community; government, employers and workers.

Government can create conditions favourable to raise productivity in the following manner :

(*i*) By having balanced programme of economic development.

(*ii*) By taking steps necessary to maintain employment.

(*iii*) By trying to make opportunities for employment for those who are unemployed or under employed, and for those who have lost their jobs as a result of productivity improvement in individual plants.

Management (Employer) can raise the productivity by :

(*i*) Balancing the use of one resource against another and by co-ordinating the efforts of everyone in the organisation to achieve the best results.

(*ii*) Motivating workers through the introduction of incentive schemes.

(*iii*) Maintaining good relations with the workers to seek their co-operation.

(*iv*) Keeping equipment and machinery in good working condition and planning the work to have effective utilization of the available resources.

Workers fear that raising productivity will lead to unemployment. Therefore, workers can help to raise productivity only when they are assured of adequate assistance in meeting their problems. Trade unions and workers representatives should actively encourage the workers to extend their whole-hearted co-operation to management in raising productivity for the benefit of the country as a whole.

40.7. IMPROVING PRODUCTIVITY BY REDUCING WORK CONTENT

Work content means the amount of work "contained in" a given product or process measured in man-hour or machine-hour.

Total work content = Basic work content + Excess time.

The basic work content is the time the product would take to manufacture or the operation to perform, if the design or specification was perfect, if the process or method of manufacture or operation was perfectly carried out, and if there was no loss of working time for any cause during the period of operation (other than the legitimate rest pauses permitted to the operative).

Thus basic work content is the irreducible minimum time theoretically required to produce one unit of time.

The excess time = Time due to defects in design or specification of the product + time due to inefficient methods of manufacture or operation.

In addition to excess time in actual practice interruptions occur, causing the worker or machine or both to remain idle. This is called as ineffective time. Thus, ineffective time is the time for which the worker or machine or both remain idle due to the shortcomings of the management or the worker. Therefore, these features (Excess time + Ineffective time) that cause unnecessary work can be considered as reasons of low productivity and elimination of these will result in improvement of industrial productivity.

The following table shows the elements of excess work contents, ineffective time and the techniques to eliminate them for improving productivity.

Causes for low productivity	*Technique to eliminate the causes*
Excess time	
A. *Work content added due to defects in design or specifications of product*	

1) Improving the existing method of Plant operation
2) Purpose of ope.
3) Design of part
4) tolerance and specifications
5) Effective utilization of materials
6) process of mfg
7) set of tools
8) working conditions
9) Improving handling of Plant layout

The first step is to gather all information about the process and present this in a form suitable for study. Information gathered may include all operations, facilities, transportation facilities used, distances moved, all inspections, inspection time, storage facilities and time spent in storage, all drawing and design specifications. This information may be presented in the form of flow process chart.

The usual technique is the critical examination which consists of asking questions on every activity shown on the flow process chart and then find out the best possible answer.

Typical questions asked may be :

(*i*) Is the operation necessary ?
(*ii*) Are too close tolerances really necessary ?
(*iii*) Can a more economical material be used ?
(*iv*) Can a better equipment or machine tool be used ?

The answers to these questions may result in the elimination or combination of some of the elements of operation ; improvement in the plant layout ; rearranging the operations in an efficient way, proper selection of machines and tools ; reduction of scrap and improvement in quality of the products manufactured.

(2) Purpose of operation. Before accepting any operation as absolutely necessary, the analyist should determine the purpose of the operation. So, it may be found that some operations are unnecessary. Sometimes an unnecessary operation will develop because of :

(*i*) Improper performance of previous operation, a second operation must be done to touch up or make acceptable the work done by the first operation.
(*ii*) *For greater sales appeal.* The study of the flow process chart will result in the elimination of some unnecessary operation, combination of some of the element operations or rearranging the operations in a best possible sequence which will reduce the time required to perform the work cycle.

(3) Design of Part. The product designs are not permanent, they can be changed, improvement is possible. To improve the design the production engineer should keep in mind the following points that may be helpful in reducing the cost of design under study.

(*i*) Reduce number of parts, thus simplifying the design.
(*ii*) Reduce the number of operations and length of travel in the manufacturing by joining parts better and making the machining and assembly easier.
(*iii*) Utilize a better and economical material.
(*iv*) Rely for accuracy upon key operations.
(*v*) Install efficient system of quality control.
(*vi*) Standardize the materials, processes, tools used and the sequence of operations etc.

(4) Tolerance and specifications. Functional designers have a tendency to specify closer tolerance than necessary while developing the products for the following reasons :

(*i*) Lack of appreciation for the increased cost because of rigid specifications and close tolerances.
(*ii*) Lack of knowledge of the production processes.
(*iii*) Considering the tendency of shop personnel to loose up the tolerances.
(*iv*) Lack of information about process capability.

Enforcing tolerances that are too tight tends to increase cost of production, for the following reasons :

(*i*) To meet tight tolerances costly precision machines, costly tools, jigs, fixtures, special materials, costly processes; skilled, trained and experienced operators may be needed.
(*ii*) The operator has to pay more attention and the rate of production may also be reduced.
(*iii*) The cost of inspection, testing and analysis will increase.
(*iv*) Because of tight inspection standards the cost of spoilage, rework is also increased, since the number of rejections will be more.

On the other hand if the tolerances are too liberal, the value of the product decreases. If is difficult to achieve interchangeability of manufacture. Therefore, instead of having tight tolerances which are loosely enforced, design realistic tolerances and create controls needed to enforce them strictly. The designers may

consult the production engineers and cost analysis group for setting realistic tolerances. The design should be optimum based on type of customers in the market.

(5) Effective utilization of materials. There are many industries in which the cost of material is a big percentage of the cost of the finished product. Many industries have to import a very large proportion of their basic raw materials and pay for them in scarce foreign currencies. Under either of these conditions higher productivity can be achieved through proper use of materials and reduction of scrap.

The material to be used is actually specified by the designer but the production engineer should try to find out alternative economical materials which will not affect the proper functioning of the product.

The following considerations will serve as a guide for selection and effective utilization of the material.

At the design stage :

(*i*) By ensuring that the product can be manufactured with the least possible use of materials, especially when they are scarce or costly.

(*ii*) By ensuring that plant and equipment selected is the most economical possible in terms of materials consumed in its operation (*e.g.* fuel) for a given level of performance.

At the process or operation stage :

(*iii*) Finding less expensive alternative material.

(*iv*) Using right process and by ensuring that it is operated correctly.

(*v*) Using material more economically by proper inventory control.

(*vi*) Training the workers properly and motivating them so that they will not turn out faulty work which has to be rejected, leading to loss of material.

(*vii*) Searching for the possible use of scrap material.

(*viii*) By using suitable material handling system to prevent the damage of material.

(*ix*) By using suitable storage facilities at all stages.

(*x*) Reducing scrap by installing inspection stations at the required stages of production.

(*xi*) By proper packing to avoid damage in transit to the customer.

(*xii*) Using standard material in standard sizes.

(6) Process of manufacture. There are many manufacturing processes, moreover, a part or component can be manufactured by two or more processes. The process selected must be an economical balance of material manpower, product design, tooling and equipment, plant space and other factors influencing cost and practicability. The break even analysis discussed earlier may be used for selection of the economical process for given volume of production. In order to reduce the cost considerably, proper speeds and feeds should be used, the grinding of cutting tool should be proper to enhance the rate of production and reduce the number of regrindings. Cutting tools should be properly mounted and right lubricant should be used. Proper maintenance will ensure that plant and machinery is operating properly and will prolong its life, so reducing capital expenditure.

(7) Set up and tools. The amount of special tooling (such as jigs and fixtures) that proves advantageous depends upon :

(1) The quantity to be produced.

(2) The chance for repeated orders.

(3) The amount of labour involved.

(4) Delivery requirements.

(5) Amount of capital requirements.

The economic advantage of lower labour costs is the controlling factor in the determination of the tooling. Other considerations such as improved interchangeability, increased accuracy, reduction of labour trouble, increased rate of production are dominant reasons for use of jig and fixtures.

Set up times depends on tooling considerations since it determines the set up time and tear down time. When the ratio of set up time to production run time is high, then the methods engineer should develop possibilities for set up and tool improvement.

It is necessary to :

(1) reduce set up time by better planning and production control.

(2) design tooling to utilize the full capacity of the machine.

(3) introduce more efficient tooling.

(8) **Working conditions.** Working conditions means the condition of the plant where the actual work is carried out. Working conditions should be good, safe and comfortable. Experiments proved that plants providing good working conditions have more productivity. Ideal working conditions will improve the safety record, reduce absenteeism and tiredness, raise employee morale, help to motivate the workers to improve their efficiency and hence enhance the productivity. Some common conditions for improving working conditions are :

(*a*) *Lighting.* Good lighting is very much essential for health, safety and efficiency of the worker. Good visibility of the equipment, the product and the data involved in the work process is an essential factor in accelerating production, reducing the number of defective products, reducing waste and preventing visual fatigue and headaches amongst the workers. More over, both inadequate visibility and glare are frequently a cause of accidents.

Lighting should be adopted to the type of work, also the level of illumination should be increased not only in relation to the degree of precision of the work but also in relation to the worker's age, since older people require a higher level of illumination than young persons. Lighting intensity at the work should be checked periodically and all lighting surfaces should be kept clean. In general, the light should be uniformly diffused and shadows that are too pronounced should be avoided. Natural lighting should be used wherever possible, through windows which should have an area equal to at least one-sixth of the floor area.

(*b*) *Control of Temperature.* If productivity is to be maintained, climatic conditions at the workplace must not place an extra burden on the worker, this is also a factor in safeguarding the worker's health and comfort. Too low temperature causes shivering, too high temperature may cause headache, fatigue, with accompanying slow down in production. Too high humidity (as in textile mill) causes uncomfort, fatigue, and drowsiness. Excessive dry air can be a source of respiratory diseases, consequently, this should be avoided in winter in overheated premises.

Hence, a temperature of 20° to 24°C may be maintained for human comfort round the year with the relative humidity within a range of 40 to 70 percent.

(*c*) ***Provide adequate ventilation.*** It has been found that disagreeable fumes, gases, dust, odour causes fatigue that taxes the physical efficiency of the worker and often creates a mental tension ; with accompanying reduction in quality and quantity of production.

Natural ventilation, obtained by opening windows or wall or roof air vents, can produce significant air flows. Where natural ventilation is inadequate, artificial ventilation has to be used. Wherever there are large emissions of gas, vapours, mists, fumes or dust, it is perferable to install exhaust ventilation, which promotes the convection of heated air and avoids the dispersion of pollutants into neighbouring premises.

(*d*) ***Control sound.*** Both loud and monotonous noises are conducive to worker's fatigue, it may also annoy the persons, interfere with communications and create difficulties in doing precision work. Therefore, noise levels should be controlled to maintain good efficiency and morale of the workers.

The most effective method of noise control is to reduce the noise at source, for example, replacing noisy machines or equipment by less noisy ones. The second method is to prevent or reduce noise transmission by the installation of noise-absorbent barriers between the noise source and the workers, or by isolating the noisy sections in separate premises or a soundproof enclosure. Personal noise protection, may also be used which consists of ear-plugs made from glass fibre or foam plastic.

(*e*) ***Promoté orderliness, cleanliness and good housekeeping.*** It has been investigated that a large percentage of accidents are due to the poor housekeeping practices.

A good housekeeping programme helps to :

(1) eliminate fire hazards.

(2) reduce accidents by providing clear passage ways for the movement of men and materials.
(3) improves employee morale.
(4) saves space which could be used for productive purposes.

Cleanliness helps to protect the workers against infection, accidents and occupational diseases.

(f) Arrange for disposal of irritating and harmful dusts, fumes, gases etc. Residues which may be the source of dangerous emissions of vapour, gases or dust (such as toxic liquids, refractories, asbestos and lead oxide) should be collected in a suitable way, dust should be removed by vacuum cleaners or wet methods and chemicals be neutralised or diluted.

(g) Provide necessary personnel protective equipment. For certain occupational hazards, neither technical prevention nor administrative arrangements can ensure an adequate degree of protection. In such cases protective devices such as goggles, face shields, welding helmets, apron, gloves, shoes, respiratory equipments, ear plugs etc. should be provided wherever necessary. This may help to reduce the accidents, improve the morale of the workers and thus raise productivity.

(9) Material Handling. Material handling increases the cost of the product, so it should be minimized as far as possible. The production engineer should adopt the following objectives related to the material handling.

(1) As far as possible reduce material handling by using mechanical equipment and a good plant layout.
(2) Reduce time spent in picking up and handling the materials by installing efficient material handling system.
(3) Make better use of existing handling facilities by proper planning and scheduling.
(4) Handle material with great care to prevent its damage and reduce chances of accidents.
(5) Maintain the material handling equipment by routine check ups and periodic maintenance.

(10) Plant Layout. Plant layout should be designed to introduce maximum economy during machining operation. The plant layout should be such that the material flows smoothly from one operation to the next without any delay. The machines and various departments should be located such that there is no back tracking, long moves and work stoppages because of dealy in transporting the material from one operation to another. Storage areas should be properly arranged to minimize searching and handling. For better worker efficiency service centres should be located close to production centres. There should be enough space for the worker to move and operate. Passageways between working places, roads, tracks etc., must never be obstructed. Material handling equipment must be properly installed.

Motivation. Worker's motivation plays an important part in increasing the productivity. Worker's motivation has a great influence on what he does or what he does not do. Therefore, motivating workers towards the achievement of high productivity, is most important.

Worker's motivation is the result of his inner forces, such as :

(*i*) Social and physical conditions of his job.
(*ii*) Organisational attitude (human relations, industrial relations).
(*iii*) Unions influence on him.
(*iv*) His needs, standard of living etc.

Some of the forces may be positive which can result in motivation, improved performance and increased productivity.

Most of the managements motivate the workers by providing them financial incentives and improved working conditions :

On and off the job. It has been investigated that good physical working conditions and high morale are essential for efficient working. Money is not only the factor to motivate the workers for higher productivity. It is a human problem, and therefore, it is essential that the management should make a humanistic approach to motivate the workers. It is more related to the behaviour of the management. The worker should feel that he is an important identity of the organisation.

40.9. "SIX LINES OF ATTACK" TO IMPROVE THE PRODUCTIVITY

Work-study plays a greater role to improve the productivity. Six lines of attack to improve the productivity can be stated as :

A { 1. Improve the basic process by research and development.
  { 2. Provide more and improved physical means to motivate the workers.

B { 3. Simplify and improve the product and reduce the variety i.e. standardize the product.

C { 4. Improve the methods of operation.
  { 5. Improve organisation, production planning and control.
  { 6. Improve manpower efficiency at all levels.

A. Sometimes, it is known as long term planning and it requires capital for implementation.

B. It is known as effective planning and can be implemented immediately. It may or may not need capital investment.

C. This phase is known as short term planning and can be immediately implemented. It may not need capital investment.

It is always recommended to get immediate results by implementing short term planning. For short term planning, work study is the most popular technique and it can help to solve all sorts of problems concerning productivity.

40.10. PRODUCTIVITY AND FATIGUE

It has been observed that the rate of production increases during the first few hours but, thereafter, output starts falling and then goes on declining steadily till the day lasts, i.e. the principles of diminishing return applies to human energy also. Reduced output represents an over-manifestation of fatigue, which is caused by diminishing of working capacity caused by length or intensity of some activities (prolonged, monotonous activities). Hence, elimination of unnecessary fatigue or minimization of fatigue will help to improve the industrial productivity.

Unnecessary fatigue is the decreased capacity for work, induced not only by the nature of work but also by unfavourable working conditions and methods. Work study can help to reduce this unnecessary fatigue to a large extent.

40.11. RELATIONSHIP BETWEEN PRODUCTIVITY AND STANDARD OF LIVING

Standard of living means the degree of material well-being available to a person or class of community which is necessary for sustaining and enjoying life. The standard of living of the representative person or family in the different countries of the world varies greatly from country to country and even, within each country, from community to community. Today, inspite of the immense efforts in too many parts of the world the ordinary man is still hardly able to satisfy his basic needs.

The basic needs that must be met in order to attain a minimum decent standard of living are : food, clothing, shelter, security and essential service. Food, clothing and shelter are generally things which a man has to obtain for himself. In order to have them he must pay for them either in terms of money or work. Security and essential service are generally matters for government and other public authorities, the individual citizen has to pay for them. So each man must earn enough to pay his contribution to the common services as well as to support himself and his family. Whenever there is unemployment or under employment, efforts to increase employment are very important and should go hand in hand with efforts to increase the productivity of those who are already employed.

In order to increase standard of living it is therefore necessary to have :

(1) More and cheaper food by increasing the productivity of agriculture.

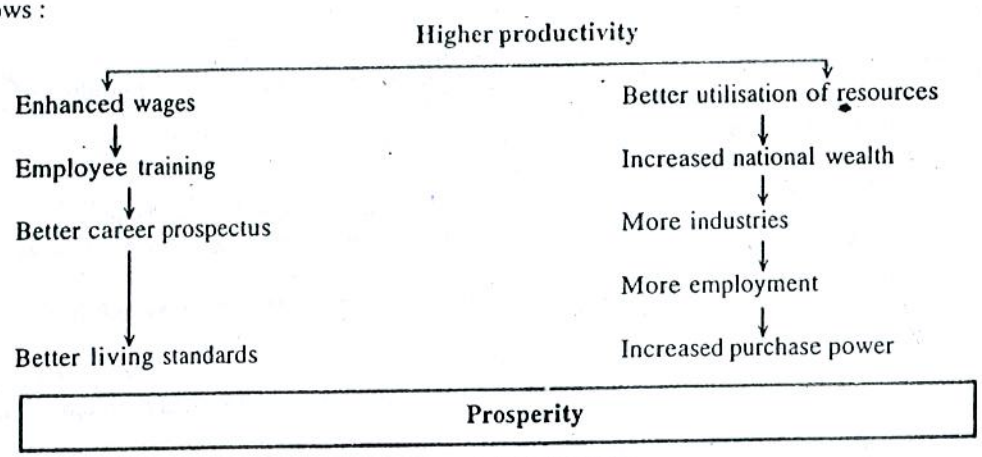
(2) More and cheaper clothing and shelter by increasing the productivity of an industry.

(3) More security and essential services by increasing overall productivity and earning power.

Therefore, it is clear that higher productivity can contribute to a higher standard of living. If more is produced at the same cost, or the same amount is produced at less cost, there is a gain to the community as a

whole which can be used by members of the community to acquire more and better goods and services and to improve their standard of living.

The relationship between productivity and standard of living can be represented diagrammatically as follows :



40.12. THE BENEFITS OF INCREASING PRODUCTIVITY

(a) For management :
(1) To earn good profit because of reduction in costs.
(2) To sell more, to earn profit.
(3) To have better utilization of resources.
(4) To stand better in the market.
(5) Provide overall prosperity and reputation of the company.

(b) For workers :
(1) Higher wages.
(2) Better working conditions, improved morale.
(3) Higher standard of living.
(4) Job security and satisfaction.

(c) For consumers :
(1) Better quality goods at reduced prices which helps to raise their standard of living.
(2) More satisfaction.

(d) To Government :
(1) Higher profits earned by factories will bring more revenue to the government by taxation.
(2) Export trades may develop bringing more foreign exchange to the nation.
(3) It helps to increase the welfare of the nation and development of national economy.
(4) It helps better utilization of resources of the nation.
(5) It increases per capita income.
(6) Development of the nation.

QUESTIONS

1. Explain the meaning of productivity with suitable examples.
2. Differentiate between production and productivity.
3. Define productivity. How would you measure productivity ? Explain.
4. Describe the various kinds of partial productivity measurement.
5. Explain the importance of productivity.
6. Explain the concept of improving productivity by reducing work content.
7. Describe the various ways to improve productivity.

8. State the role of Govt., employer and workers for productivity improvement.
9. Describe the effects of any four of the following on productivity :
   (*a*) Tolerance and specifications.
   (*b*) Working conditions.
   (*c*) Plant layout.
   (*d*) Combined operations.
   (*e*) Manufacturing process.
   (*f*) Design of part.
10. Write short notes on :
   (*a*) Role of motivation in improving productivity.
   (*b*) Productivity and fatigue.
   (*c*) "Six lines of attack" to improve productivity.
   (*d*) Total productivity.
11. State the benefits of increasing productivity to :
   (*a*) Management.
   (*b*) Workers.
   (*c*) Society.
12. "Productivity is a means for increasing the welfare of the nation". Justify the statement.
13. Explain how method study can lead to higher productivity.
14. Explain the relationship between productivity and standard of living.