CHAPTER 2

Theories of method study and work measurement

Work study

Work study is a term used to embrace the techniques of *method study* and *work measurement* which are employed to ensure the best possible use of human and material resources in carrying out a specified activity.

Work study is thus especially concerned with productivity, since it is used to increase the amount produced from a given quantity of resources with minimum capital investment.

International Labour Office (1970) stated...

"Method study and work measurement are closely linked. Method study is concerned with reduction of operation work content, while work measurement is concerned with investigation and reduction of ineffective time and the subsequence establishment of time standards for operations on the basis of work content as established by method study".

The influence of method study and work measurement permeats the entire production system (Figure 2.1). The central positions of methods and measurement groups make them a fertile training ground for new management material ; neophyte managers can work with the elements of production and observe the cross-flow of ideas, ideology, and occasional idiocy. It is a prime position to spot suboptimization

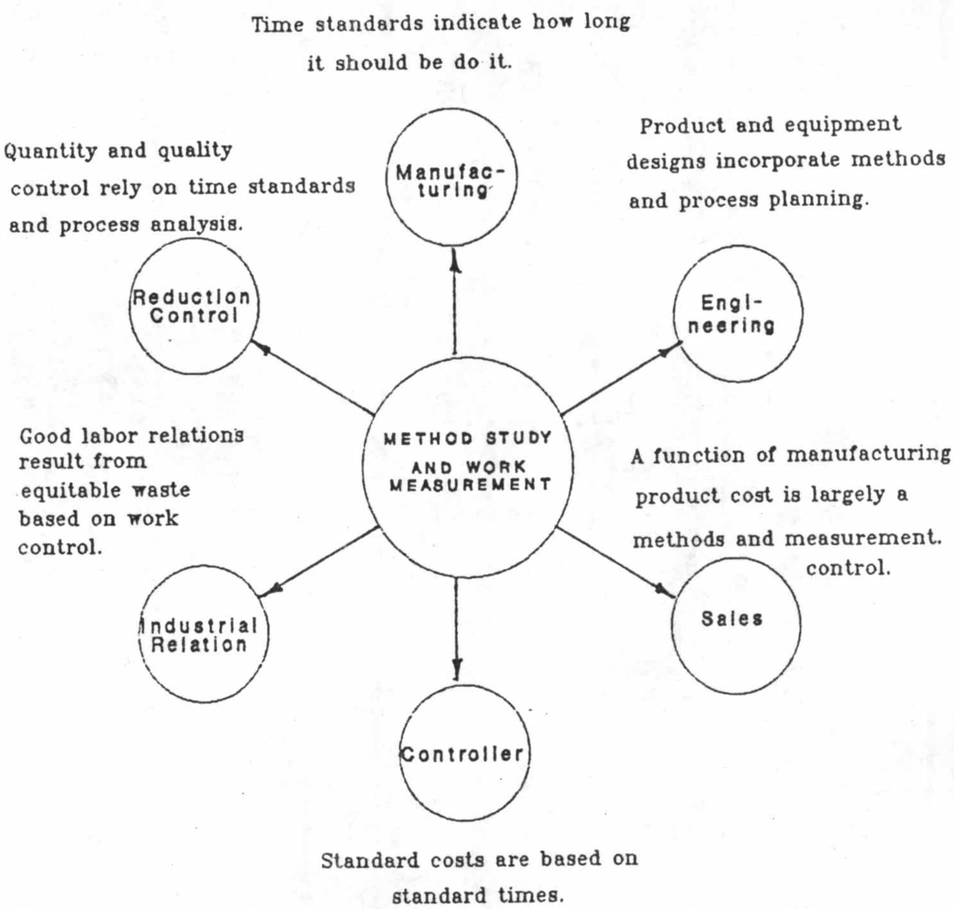

Figure 2.1. The influence of work methods and measurement effort on other production activities.

and to apply creative countermeasures.

As can be seen from Figure 2.2,both method study and work measurement are composed of a number of different techniques. Although method study should precede the use of work measurement when time standards for output are being set, it is often necessary to use one

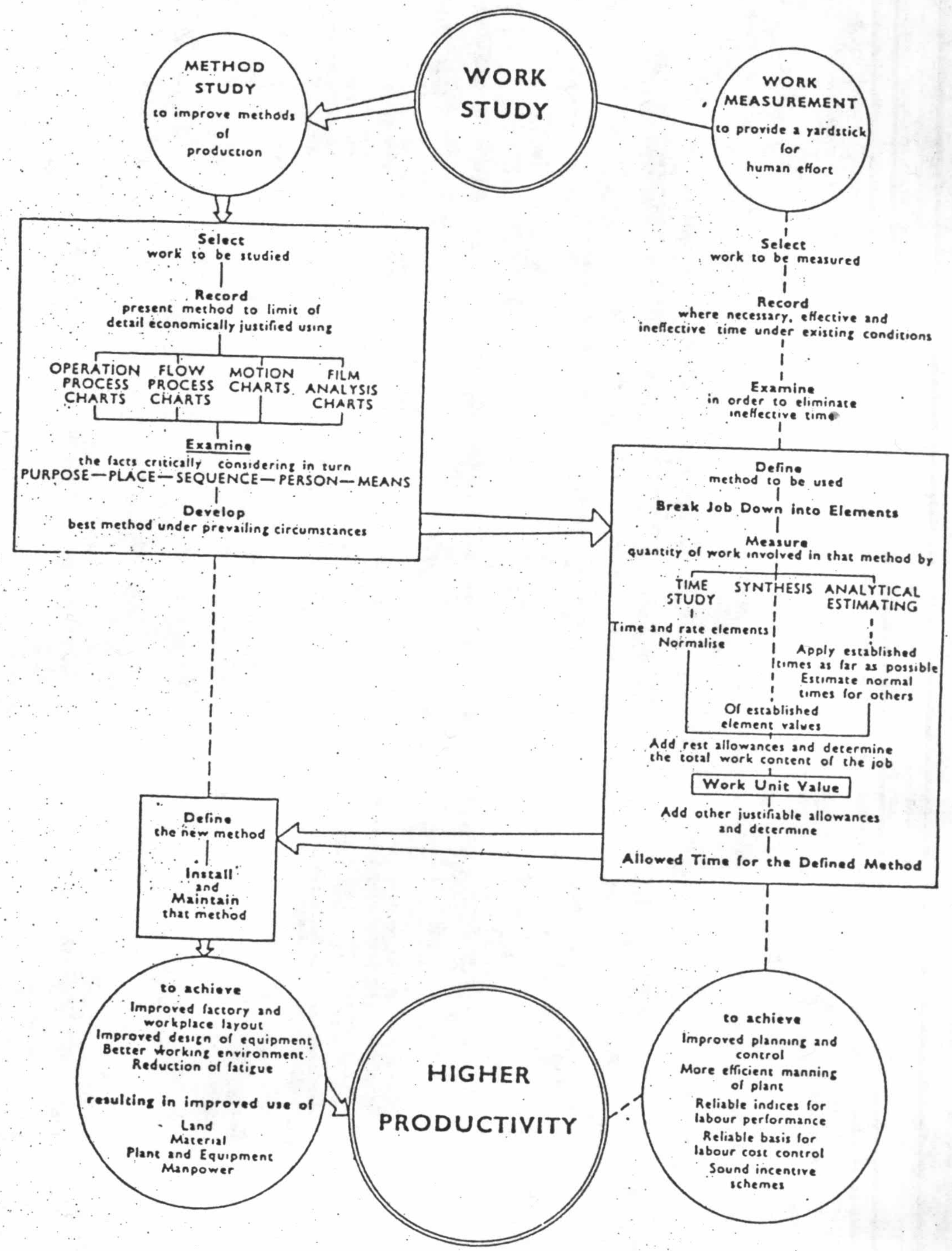

Figure 2.2. The inter-relation between method study and work measurement.

of the techniques of work measurement in order to determine where ineffective time is occuring and to determined its extent. Management action can be taken to eliminate it before method study is begun.

International Labour Office (1970) described that here are eight basic steps in a typical work study. Three steps are common to the procedures of both method study (M.S.) and work measurement (W.M.), three are M.S. steps and two are W.M. steps. They are as follows:

1. *Select* the job or process to be studied (M.S. & W.M.).
2. *Record* from direct observation (M.S. & W.M.).
3. *Examine* the recorded facts critically and challenge everything that is done (M.S. & W.M.).
4. *Develop* the most economic method (M.S.).
5. *Measure* the quantity of work and calculate a standard time for its performance (W.M.).
6. *Define* the new method and the related time so that it can always be identified (W.M.).
7. *Install* the new method as agreed standard practice with the time allowed (M.S.).
8. *Maintain* the new standard (M.S.).

Method study

The objects of method study are :

The improvement of processes and procedures.

The improvement of factory, shop and workplace layout and of the design of plant and equipment.

Economy in human effort and the reduction of unnecessary fatigue.

Improvement in the use of material, machines and manpower.

The development of a better physical working environment.

In order to understand the problem fully it is necessary to carry out a critical evaluation of the present method. Several approaches appear in the literature, but it is proposed to consider that which is usually referred to as the *questioning techniques.*

The questioning technique centers around the use of the questions *what, why, when, who,* and *how.* The format of this questioning technique is shown in Table 2.1.

Table 2.1. Work study questioning techniques

5W 1H	Type	Meaning	Consideration	Method
What	Title	What is done? What else might be done?	Can abandon it or not? Have another methods to achieve it or not?	ELIMINATE unnecessary parts of the job
Why	Purpose	Why is it done? Why is it necessary?		
When	Sequence	When is it done? Why is it done then?	Can re-sequence ?	COMBINE whenever possible or REARRANGE the sequence of operations
Where	Place	Where is it done? Why is it done there?	Can do it another place?	
Who	Person	Who (which machine) does it?	Can it do by another person	

Table 2.1 (continue). Work study questioning techniques

5W 1H	Type	Meaning	Consideration	Method
Who	Person	Who (which machine) does it? Why does that person (machine) do it?	Can it do by another person (machine)?	the sequence of operations for more effective results
How	Means	How is it done? Why is it dont that way?	Can reduce effort and time or not?	SIMPLIFY the operation

The choice of jobs to be tackled by method study in any factory (or other place) where materials are moved or manual work is carried on is usually a very wide one. Table 2.2 gives the general field of choice, starting from the most comprehensive investigation covering, possibly, the whole operation of the plant and working down to the study of the movements of the individual worker. Both type of job and techniques by which it may be attacked are listed. It should be pointed out that, in the course of a single investigation, two or more of these techniques, even all of them, may be used.

Table 2.2. Typical industrial problems and appropriate method-study techniques.

Type of job	Technique	Examples
Complete sequence of manufacturer	Operation process chart. Flow process chart.	Manufacture of an electric motor from raw material to despatch.
Factory layout: movement of materials	Flow diagrams. Models.	Movement of a workpiece through all machining operations.
Factory layout: movement of worker	String diagram.	Workers servicing spinning machinery with bobbins.
Handling of materials	Flow process chart. Flow diagram. String diagram.	Manual handling workpieces by handtruck in shop floor. Loading lorries with finished products.
Workplace layout	Operation process chart. Two-handed process chart.	Light assembly work on a bench.
Gang work or automatic-machine operation	Multiple-activity process chart. Man/machine process chart.	Assembly line. Operator looking after semi-automatic lathe.
Movements of operatives at work	Video tape. Simo chart.	Female operatives on short-cycle repetition work. Operation demanding great manual dexterity.

Work measurement

The Measurement of work has been a primary pursuit of industrial engineers and their predecessors since Frederic W. Taylor utilized the stopwatch in 1883. Prior to the scientific measurement of work, tasks were standardized by the use of historical production data or estimates. Mishra (1987) stated that the result of work measurement is a time standard or a work standard, which may be expressed as pieces per minute (or hour or day), minute per piece, or in some other useful forms.

Figure 2.3 illustrates an idealized cost-benefit relationship of the various work-measurement techniques.

Curve A represents the sum of the cost of development (and implementation) of the work measurement system and annual operating cost to maintain labor standards and management control systems. Curve B is the cost of inaccuracy in labor standards or the opportunity cost for an operation standardized with a given work-measurement technique. Curve C is the sum of Curve A and B. The most economical strategy for standardizing and controlling an operation is indicated by the least-cost portion of Curve C. Although the cost-benefit ratio is the ideal selection criterion for the best work-measurement technique, other factors can prove to be overriding, such as the caliber of supervision, accuracy of labor standards required for disciplinary actions, and management urgency for program savings.

work measurement encompasses all activities performed by an individual or a team in manufacturing, warehousing, and administrative operations. Therefore, as illustrated in Figure 2.4, produced by WOFAC,

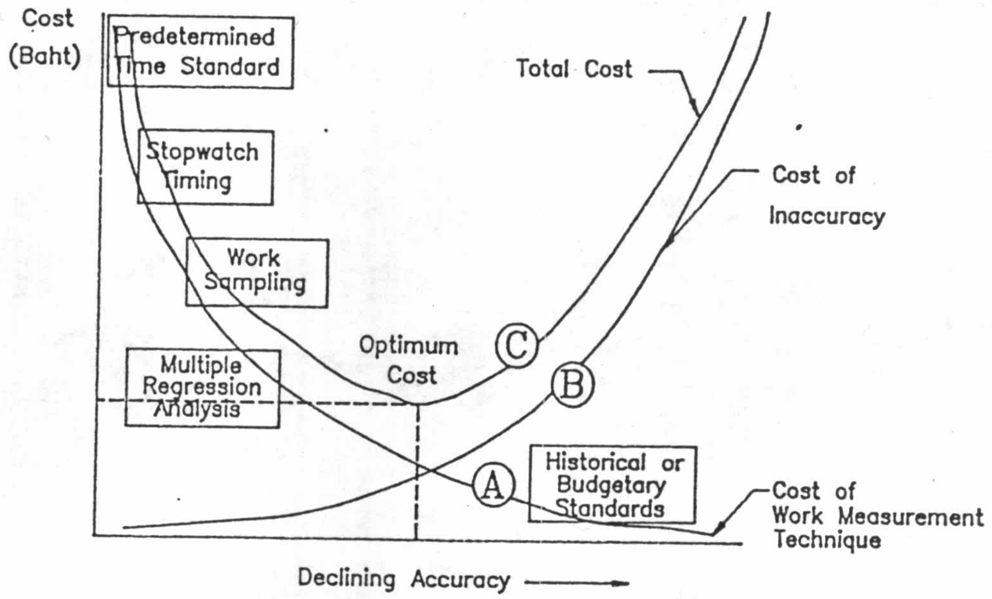

Figure 2.3. Cost vs. inaccuracy of work-measurement techniques.

activities and all operations are measurable using the various techniques enumerated above. As the type of work changes from repetitive high volume to nonrepetitive low volume, the measurement technique changes from the more familiar predtermined time standards and stopwatch to the less fimiliar multiple regression analysis, work sampling, etc. In addition, the unit of measurement changes from units or parts per hour to crew size or manning tables.

There are many reasons for wanting to know the amount of time a particular task should take to accomplish. It may simply be for reasons of curiosity. But, realistically, it is for any of three reasons : to accomplish planning, to determine performance, and/or to establish costs.

When the time to manufacture and assemble various parts and/or components is known, it provides an opportunity to analyze important production issues as follows :

- the total labor cost of the product.
- the number of production workers needed.
- the number of machines needed.
- the overall production schedule.
- the feasibility of entering into production of the product, and the actual cost of production.

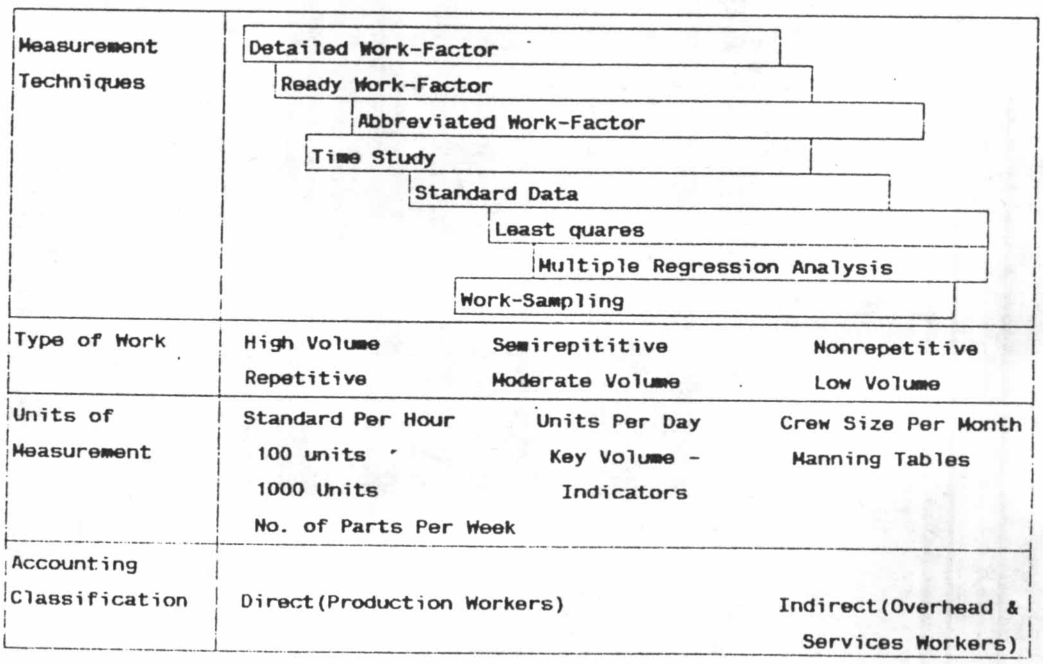

Figure 2.4. Common applications of work measurement techniques.

As a consequence, a manager can achieve an even and sufficiently high utilization of personel, material, and equipment. This can result in an overall efficiency that will allow an organization to survive and grow.

Several techniques are used for the measurement of work, depending on the accuracy required for the labor standard, availability of resources, nature of the activity, and management objectives. Some of the techiques are historical data, estimates, time study, predetermined times, standard data, work sampling, and mathematical tools.

Predetermined time standards

Predetermined time standards are standard data systems that are designed to be used in a wide variety of product and process applications. These systems of times have been designed either as a general purpose system, with the intention of being applicable to all types of jobs, or as special purpose data, with applications to just one type of work such as punching, bending, shearing.

Some of the better known predetermined time systems include Methods Time Measurement (MTM), Work Factor (WF), Maynard Operation Sequence Technique (MOST), Motion Time Analysis (MTA), Basic Motion Time Study (BMT), Dimensional Motion Time (DMT), and many others. Some techniques will be described below.

Method time measurement

Method Time Measurement (MTM) is a procedure which analyzes any manual operation or method into the basic motions required to perform it and assigns to each motion a predetermined time standard which is based on the nature of the motion and conditions under which it was made.

The basic objective of MTM is to optimize methods as well as to set standards. It offers the great advantage of making it possible to plan and develop accurate methods before production starts, eliminating the need for changes in methods in the middle of the production run. The MTM system allows the establishment of engineered time standards without the use of stopwatch,and subsequent performance rating of the operator.

MTM is a system of established basic work motions and the time allowed for their performance. The MTM system also established the laws and concepts of how and why motion patterns are made by operators with normal mental and physical qualifications.

The MTM procedure consists not only of data tables which establish basic work motion under a variety of conditions, but also of the time for their performance which serves as the basis of measurement of any manual operation. It defines the path about which the sequences of motion will follow, much as the laws of physics explain mathematically the expected material results that will be encountered under varying physical conditions.

MTM-1 is the basic-level MTM system from which all other systems of the MTM family have been developed. The second level of the family is MTM-2, which has a speed of analysis twice as great as the basic level, but has lower accuracy. The third level is MTM-3, whose speed of analysis is seven time greater than MTM-1. It is used where a less detailed methods description is required.

Another variant of MTM is the Modular Arrangement of Predetermined Times (MODAPTS), developed as a generic and functional second-level system.

Work factor

Work factor is defined as an elemental time system for compiling time standards to establish the expected productivity of a human performing useful manual and mental work. Stopwatches and other timing devices are not used with work factor except for machine or process times.

There are four levels or integrated systems of work factor to accomodate the industrial situation. These include :

Detailed Work Factor - for highly repetitive, short-cycle operations. Work factor time unit equals 0.0001 minute.

Ready Work Factor - for longer cycle and less repetitive operations. Work factor time unit equals 0.0010 minute.

Abbreviated Work Factor - for custom operations with very little repetition, such as toolroom operations. Work factor time unit equals 0.0050 minute.

Work Factor Standard Data - for rapid standard and rate setting in all production operations.

Work sampling

Work sampling is a measurement technique for quantitative analysis (in terms of time) of the activities of men, machines or any observable state or condition of operation. It is especially useful in the analysis of nonrepetitive or irregularly occuring activity, where no complete methods and frequency description are available. A work sampling study consist of a large number of observations taken at random intervals. In taking the observation, the condition of the object of study is recorded,and this condition is categorized into predefined groups of activities perculier to the particular work situation.

Work sampling can be used to set standards, but to do so requires that an accurate record be maintained of the work turned out during the course of the study, and with each observation there must be a recording of operator performance rating. However, it is not recommended to set standards with work sampling unless an analyst is quite proficient in work sampling.

Maynard operation sequence technique

MOST, an MTM-based system, is applicable for any cycle length and repetitiveness, as long as there are variations in the motion pattern from one cycle to another. The system employs a small number of predetermined models of fixed activity sequences that cover practically all aspects of manual activity. It appears that there is a large category of operations for which the consistent behavior of MOST will produce standards with accuracy approximately equivalent to that of higher-level system, but with for less effort and in far shorter time.

The MOST Work Measurement Systems can be classified to *Basic MOST, Mini MOST, Maxi MOST,* and *Clerical MOST.* Basic MOST is routinely used to analyze the very wide range of manual operations most common to industry. Mini MOST provides detailed analysis of highly repetitive operations, (such as small assembly and the packaging of small items). Maxi MOST is used for longer cycle operations, such as setups, maintenance, material handling, heavy assembly, and job shop work. Clearical MOST, an extension of Basic MOST, is used for analysing office activities.

It was noticed that the movement of objects follows certain consistently repeating patterns, such as reach, grasp, move and position the object. These patterns were identified and arranged as a *sequence of events* (or subactivities) followed in moving an object. A model of this sequence is made and acts as a standard guide in analyzing the movement of an object. It was also noted that the subactivities in that sequence vary independently of one another in their actual motion content.

Objects can be moved in only one of two ways : either they are picked up and moved freely through space, or they are moved and maintain contact with an other surface. For each type of move, a difference of events occurs ; therefore, a separate MOST activity sequence model applies. The use of tools is analyzed through a separate activity sequence model. This gives the analysts the opportunity to follow the movement of a hand tool through a standard sequence of events, which, infact, is a *combination* of the two basic sequence models.

Consequently, only three Basic MOST activity sequences are needed for describing manual work, plus a fourth for measuring the movements of objects with manual cranes :

- The *General Move Sequence* for the spatial movement of an object freely through the air.

- The *Controlled Move Sequence* for the movement of an object when it remains in contact with a surface or is attached to another object during the movement.

- The *Tool Use Sequence* for the use of common hand tools.

MOST, like any predetermined motion time system, is concerned primarily with the motions that make up an operation. The times or index values for these motions have already been predetermined and are immediately available to the analyst from data cards or, after experience, from memory, or (even better) in the computer memory. Some data cards are shown by Figure 2.5. The responsibility of the analyst is to recognize the specific motion patterns and to assign the appropriate index values to each sequence model parameter.

The Basic MOST Sequence Models

General Move is defined as moving objects manually from one location to another freely through the air. To account for the various ways in which a General Move can occur, The activity sequence is made up of four subactivities :

A Action distance (mainly horizontal)

B Body motion (mainly vertical)

G Gain control

P Placement

These subactivities are arranged in a *sequence model* (Figure 2.6), consisting of a series of parameters organized in a logical sequence.

Basic MOST® System — A B G A B P A — GENERAL MOVE

INDEX X 10	A ACTION DISTANCE: PARAMETER VARIANT	A ACTION DISTANCE: KEYWORD	B BODY MOTION: PARAMETER VARIANT	B BODY MOTION: KEYWORD	G GAIN CONTROL: PARAMETER VARIANT	G GAIN CONTROL: KEYWORD	P PLACEMENT: PARAMETER VARIANT	P PLACEMENT: KEYWORD	INDEX X 10
0	≤2 in ≤5 cm	CLOSE					Hold Toss	THROW CARRY TOSS PICKUP	0
1	Within reach				Light object Light objects simo	GRASP (optional)	Lay aside Loose fit	MOVE PUT	1
3	1 - 2 steps	1 STEP 2 STEPS	Bend and arise 50 % occ.	PBEND	Non Simo Heavy Bulky Blind Disengage Obstructed Interlocked Collect	GET DISENGAGE FREE COLLECT	Adjustments Light pressure Double placement	PLACE REPLACE	3
6	3 - 4 steps	3 STEPS 4 STEPS	Bend and arise	BEND			Care Blind Heavy pressure Intermediate moves Precision Obstructed	POSITION REPOSITION	6
10	5 - 7 steps	5 STEPS 6 STEPS 7 STEPS	Sit or stand	SIT STAND					10
16	8 - 10 steps	8 STEPS 9 STEPS 10 STEPS	Through Door Climb on or off Stand and bend Bend and sit	DOOR CLIMB / DESCEND STAND AND BEND BEND AND SIT					16

Figure 2.5. Some data cards for Basic MOST.

Basic MOST® System		A T K F V L V P T A						MANUAL CRANE
	A	T L		K	F	V	P	
INDEX X 10	ACTION DISTANCE STEPS	TRANSPORTATION UP TO 2 TON FEET (M) EMPTY	LOADED	HOOK-UP AND UNHOOK	FREE OBJECT	VERTICAL MOVE INCHES (CM)	PLACEMENT	INDEX X 10
3	2				Without direction change	9 (20)	Without direction change	3
6	4				With single direction change	15 (40)	Align with one hand	6
10	7	5 (1.5)	5 (1.5)		With double direction change	30 (75)	Align with two hands	10
16	10	13 (4)	12 (3.5)		With one or more direction changes, care in handling or apply pressure	45 (115)	Align and place with one adjustment	16
24	15	20 (6)	18 (5.5)	Single or double hook		60 (150)	Align and place with several adjustments	24
32	20	30 (9)	26 (8)	Sling			Align and place with several adjustments + apply pressure	32
42	26	40 (12)	35 (10)					42
54	33	50 (15)	45 (13)					54

Figure 2.5 (continue). Some data cards for Basic MOST.

Basic MOST WORK MEASUREMENT TECHNIQUE		
ACTIVITY	SEQUENCE MODEL	SUB - ACTIVITIES
GENERAL MOVE	A B G A B P A	A - ACTION DISTANCE B - BODY MOTION G - GAIN CONTROL P - PLACEMENT
CONTROLLED MOVE	A B G M X I A	M - MOVE CONTROLLED X - PROCESS TIME I - ALIGNMENT
TOOL USE	A B G A B P A B P A	F - FASTEN L - LOOSEN C - CUT S - SURFACE TREAT M - MEASURE R - RECORD T - THINK

Figure 2.6. Sequence models comprising the Basic MOST technique.

The *General Move Sequence Model*, which is the most commonly used sequence model, is defined as follows:

A	B	G	A	B	P	A
Action distance	Body motion	Gain control	Action distance	Body motion	Place	Action distance

<u>Example</u> An operator gets a sheet-metal part from floor, putting it on the workbench. Assume that the operator is starting directly in front of the part, which is medium in weight, and the workbench is located 5 steps away. Then the sequence model is filled out as follows :

$A_1 \quad B_6 \quad G_3 \quad A_{10} \quad B_0 \quad P_1 \quad A_0$

(Index numbers for each parameter are chosen from data cards.)

By using the General Move keywords and sentence format, this activity would be expressed as " MOVE PART TO WORKBENCH ".

The time to perform this activity is completed simply by adding all index numbers and multiplying by 10 to convert to TMU : (1+6+3+10+0+1+0)x10 = 210 TMU.

The second type of move is described by the *Controlled Move Sequence*. This sequence is used to cover such activities as operating a lever or crank, activating a button or switch, or simply sliding an object over a surface. In addition to the **A**, **B**, and **G** parameters from the General Move Sequence, the sequence model for a controlled move contains the following subactivities :

M	X	I
Move controlled	Process time	Align

Example From a position in front of a shearing machine, the operator takes 3 steps to the side, turns the handwheel 3 revolutions, and sets the backgauge against a scale mark.

The keyword is " CRANK HANDWHEEL AT SHEARING MACHINE 3 REV., WITH GUIDE + ADJUST ".

$$A_6 \quad B_0 \quad G_1 \quad M_6 \quad X_0 \quad I_6 \quad A_0$$

$$(6 + 0 + 1 + 6 + 0 + 6 + 0) \times 10 = 190 \quad \text{TMU}$$

The third sequence model included in the Basic MOST Work Measurement Technique is the *Tool Use Sequence Model.* This sequence model covers the use of hand tools for such activities as fastening or loosing, cutting, cleaning, gauging, and recording. Also, certain activities requiring the use of the brain for mental processes can be classified as Tool Use, e.g., reading and thinking. As indicated above, The Tool Use Sequence Model is a combination of General Move and Controlled Move activities. It was developed as a part of the Basic MOST Systems, merely to simplify the analysis of activities related to the use of hand tools.

Example An operator standing in front of a notching machine uses steel tape to measure the depth cut of steel plate to see that it is correct. The steel tape is located 3 steps away on a workbench.

The keyword is " MEASURE DEPTH OF CUT USING STEEL TAPE 2 M FROM WORKBENCH AND RETURN"

$$A_6 \quad B_0 \quad G_1 \quad A_6 \quad B_0 \quad P_1 \quad M_{32} \quad A_6 \quad B_0 \quad P_1 \quad A_0$$

$$(6 + 0 + 1 + 6 + 0 + 1 + 32 + 6 + 0 + 1 + 0) \times 10 = 530 \text{ TMU}$$

The variants of parameter for each of the sequence will not examined here because of the great variety of details.

Time Units

The time units used in MOST are based on hours and parts of hours called *Time Measurement Units* (TMU). One TMU is equivalent to 0.00001 hour. The following conversion table is provided for calculating standard times:

1 TMU	=	0.00001	hour
1 TMU	=	0.036	second
1 hour	=	100,000	TMU
1 minute	=	1,667	TMU
1 second	=	27.8	TMU

The time value in TMU for each sequence model is calculated by adding the index numbers and multiplying the sum by 10. All time values established by MOST reflect the activity of an *average skilled operator* working at an *average performance level* or *normal pace*. This is often referred to as the 100 % performance level that in time study is achieved by using "levelling factors" to adjust times to defined levels of skill and effort. Therefore, when using MOST, it is *not necessary* to adjust times unless they must conform with particular high or low task plans used by some companies. This also means that a properly established time standard, using MOST or stopwatch time study, will give nearly identical results in TMU.

Comparison of techniques

Table 2.3 represents a comparison of the common work measurement techniques. The markedly divergent methods of measurement indicate the advantages in terms of cost and benefits. The Table shows that predetermined time standards offer greatest accuracy as well as a basis for method improvement. On the other hand, historical production standards provide a crude basis for work measurement.

Table 2.3. Comparison of work measurement techniques.

Criteria	Historical Production Standards	Multiple Regression Analysis	Work Sampling	Stopwatch Timing	Predetemined Time Standards
1. Engineering effect required for					
System development and implementati	Minimal	Low-medium	Medium	Medium	High
System maintenance	Minimal	Low-medium	Medium	Medium	High
2. Complexity of labor standard	None	Low	Medium	Medium high	
3. Degree of work measurement accuracy	Low	Medium	High	High	Very high
4. Provide a basis for method improvemen	None	None	Low	Medium	Very good
5. Training and skill required for operating management	Low	Low	Medium	Medium high	High
6. Employee and management acceptability standards	Fair	Fair-good	Fair-good	Very good	Good
7. Ease of labor standards enforcement	Low	Fair	Good	Good	Good
8. Effectiveness in realizing maximum sav	Very low	Fair	Fair	Good	Very good
9. Program implementation	Very short	Short	Medium	Medium-long	Very long
10. Rate of saving realization (How quickly	Very short	Short	Medium-long	Long	Long
11. Effectiveness in					
Manpower forcastingand scheduling	Fair	Average	Average-high	High	High
Performance appraisal					
Management reporting					