CHAPTER III

THEORETICAL CONSIDERATIONS

3.1 Six sigma[3]

3.1.1 What is six sigma product quality?

The six sigma concept is a relatively new way to measure how "good" a product is. When a product is six sigma it tells us that product quality is excellent. It says the probability of producing a defect is extremely low.

In order to understand more about how six sigma tells us that a product is excellent, let us define what the term "sigma" actually means in terms of quality. Essentially, a sigma is a statistical measuring device that tells us how good our products are. Using this device, we can directly measure the quality confidence we would have in a given product or process and then compare it to another similar product or process. To make things simple we will substitute the symbol "σ" for the word " sigma".

To apply this concept, we must first determining how many opportunities there are for a nonconformity or defect to occur, as related to a particular product. Then, we must count the actual number of defects associated with that during manufacturing. With this information we are now able to determine how many defects there are per million opportunities for a defect. For example, if there are 1,000,000 opportunities for a defect to occur within each of our five radios and we observe five defects (one defect per radio) then there would be one defect per million opportunities or, expressed as a fraction, 0.000001 nonconformities per million opportunities (npmo). Note that this also may be expressed as parts per million (ppm.)

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[3] Six sigma references from Mikel J. Harry,Ph. D. "The Nature of Six Sigma Quality" and Mikel J. Harry & J. Ronald Lawson "Six Sigma Producibility Analysis and Process Characteristic".

When the number of sigma units or "σ's" is small, say two, product quality is not very good. The number of defects per million opportunities for a defect would be intolerable. When the number of σ's is large, say six, quality would be excellent. The number of defects per million opportunities would be extremely small. This is illustrated in Figure 3.1.

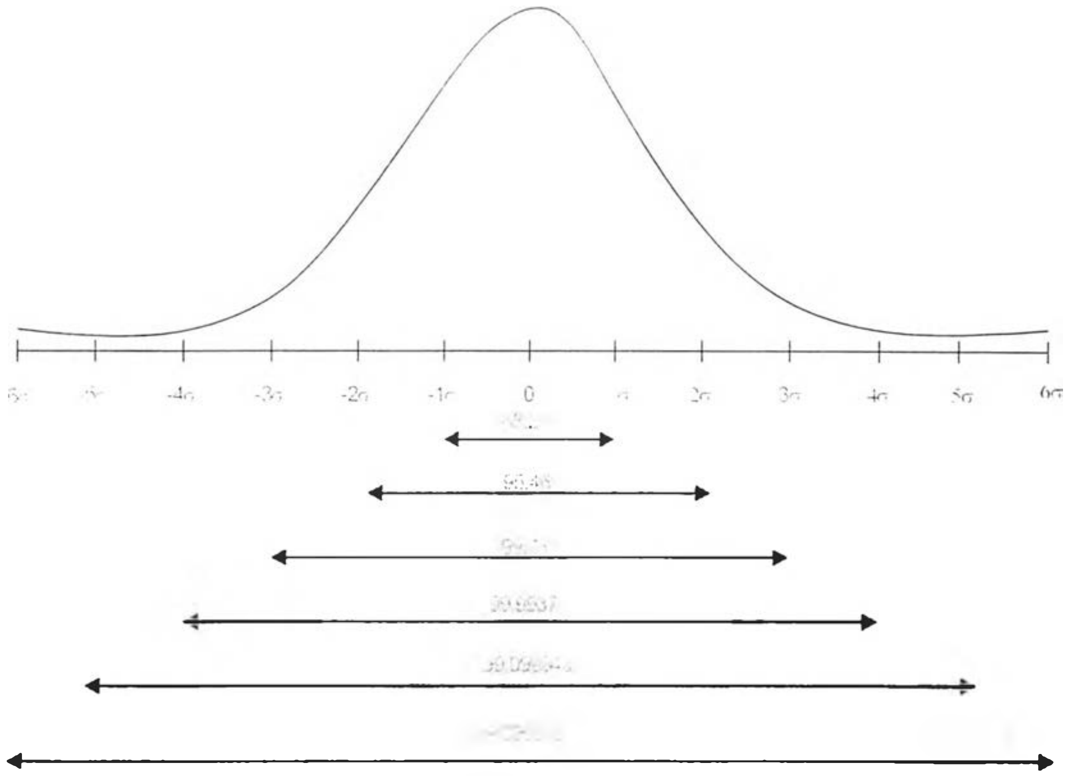

Figure 3.1 Typical Areas Under the Normal Curve.

In general, when we say that a product is 6σ, what we are really saying is that any given product exhibits no more than 3.4 ppm at the part and process step level. This number takes typical sources of variation into account. That is to say, the 6σ quality concept recognizes that a small amount of variation will be present as a result of slight fluctuations in environment conditions; differences between operators, parts, materials; and so forth. If the fluctuations can be sufficiently controlled such that a product or process characteristics stay centered on its ideal condition, there would be only 0.002 nonconformaities per million opportunities. However, nothing can be perfectly controlled to an ideal condition, some shifting and spread will be presented over the long haul. When such variation is taken into account, there would only be 3.4 ppm.

In order to help ensure that typical forms of variation – shifts and drifts in the average – do not cause excessive differences between and within units of product, there are several things that can be done.

1. First, Designers configure a product in such a manner that its performance is " shielded" against variation. By doing this, the organization can be ensure that its products will consistently perform to the specified levels; i.e. all of the product will be on target with minimum differences between units of product. When designers do this, we say they are " designing for producibility".
2. Second, thing that can be done is related to the manufacturer's process as well as the process of its suppliers. By systematically tracking down, controlling and ultimately eliminating the root causes of variation through the application of statistical process control (SPC) methods, the "spread" and "centering" of processes can be significantly improved.

When these things are done and the end result is product whose opportunity for error at the part and process step levels is, on the average, no more than 3.4 ppm, we say that the product is 6σ.

3.1.2 How to achieve 6σ quality?

In order to achieve 6σ quality, we must recognize that product variation results from insufficient design margin, inadequate process control, and less than optimum parts and material. These are the three primary sources of product variation. If we are to achieve 6σ quality in everything we do, including administrative things such as filing, typing, and documentation, we must isolate, control and ultimately eliminate variation.

To defeat the variation, we must recognize that any deviation from an ideal condition, no matter how small, represents a potential loss to our customers, as well as to ourselves. There are some of the tools that help conquer this variation include:

- Short cycle time manufacturing (SCM)
- Design for producibility
- Statistical process control (SPC)
- Supplier SPC (SSPC)
- Participative management practices (PMP)
- Part standardization and supplier qualification
- Computer simulation

Not only do these tools help us remove variation but they also help us detect the presence of the variation before we go into production. In this manner, we are able to prevent product casualties before they happen. We call this " a prior" control – control that is gained before the fact, not after something go wrong. If we do not do these things, chance is in charge; by doing them, we are in charge.

There are three basic way for winning. First, we must gain a prior control during the product and process design cycle. To do this, we must:

1. Define 6σ tolerances on all critical product and process parameters.

2. Minimize the total number of parts in the product and minimize steps that comprise all processes.
3. Standardize the parts and processes we use.
4. Use SPC principles and computer tools during the design and prototype phases.

The second strategy involves using SPC to continually isolate, control, and eliminate variation resulting from people, machines, material and environment. The third strategy involves the supplier. Our supplier must also continually strive to eliminate variation in the parts and materials by

1. Instituting a supplier qualification program which is, in part, based on SPC principles.
2. Requiring process control plans from our suppliers
3. Minimizing the total number if suppliers that are used.
4. Ensuing a long term " win-win" partnership with the suppliers that are used.

3.1.3 Six sigma process steps

If we believe that a product design should be judged on the basis of how well it integrates various elements to achieve some output, in the most efficient and cost effective manner possible, then a manufacturing process should likewise be assessed. In reality, there is no real difference between a "design" and a manufacturing "process" from an analytical point of view. Both things have elements, subelements, sub-subelements, and so on, ad infinitum. In both cases, there exists a hierarchy of causation. Even though the "nuts and bolts" are different, they both process a form of order. This order may be expressed using the following relation:

$$Y = f(X_1 \ldots\ldots X_N)$$

Where Y is a certain output parameters and X_1.......X_N are the various input and process factors. The relationship defined in above relation is to say that Y is dependent upon the Xs. The value of Y must wait upon the value of X. In short, Y is dependent upon the condition of the Xs and, conversely, the Xs are independent of Y condition. From a design point of view, a product performance requirement (Y) is dependent upon the nominal values and specification limits of the components assigned to the design. So, it goes with manufacturing.

The overall ability of a manufacturing process to consistently produce a high-quality end item is highly dependent on the capability of the individual steps that comprise that process. In turn, the capability of any given process step is determined by the degree of capability related to and the subsequent control of, the underlying factors or " variables" as they are often referred to. For example, soldering is a function of such variables as flux specific gravity, solder machine chain speed, solder temperature, and copper mass, just to mention a few. As we are all aware, not all process steps or variables equally impact the quality of the product; some are more influential than others. In the same manner that design engineers strive to isolate the quality-sensitive components that exert an undue influence on product performance, the manufacturing, process, and quality engineers must isolate those process steps and related variables that exert undue influence on the various characteristics and performance requirement tied to the product. Once the critical steps and related variables are known, the engineers must then strive to establish 6σ control.

Essentially, 6σ process capability can be realized through a relative simple four - phase approach; Measure, Analysis, Improve and Control phase.

First Phase, Measure, is related to process definition. This involves physically defining the limits of the process – where it begins and ends in relation to the total manufacturing flow. Figure 3.2 illustrates the nature of such a flow. By doing this, the limits of the battlefield are defined. Also during this phase, all of the key inspection and test parameters are identified. In addition, by means of brainstorming, all of the known independent parameters are established. In turn, these factors are formed into a Cause and Effect (C&E) matrix in order to provide process "scorecard" (Figure 3.3)

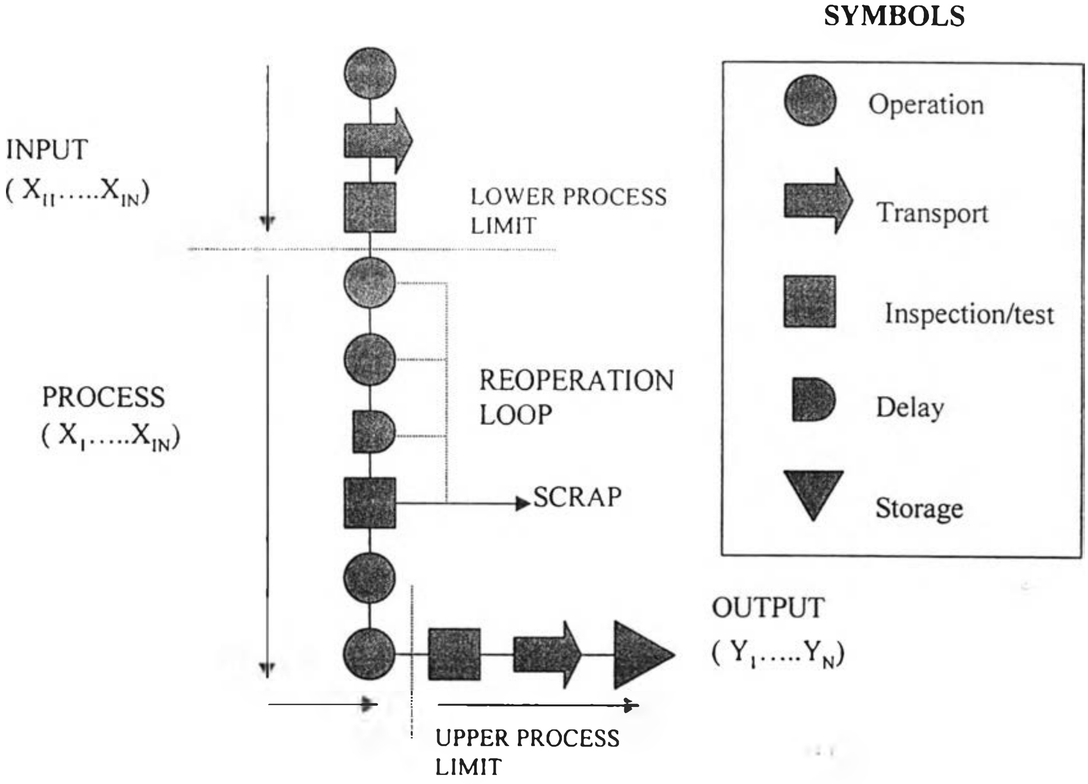

Figure 3.2 Sample Process Flow Diagram Showing the Process Limits

EFFECT:
EFFECT: PRODUCT PARAMETERS
(IMPROVEMENT OPPORTUNITIES)

CAUSE
PRODUCT PARAMETERS
(CASUAL VARIABLES)

	Y_1	Y_2	Y_3	Y_N
X_1	4	3	-	1
X_2	-	2	2	6
X_3	5	7	10	4
X_4	3	5	-	3
X_N	-	4	5	9

Figure 3.3 Sample Cause and Effect Matrix

Second Phase, Analysis phase, establishes the capability of the process to attain a certain level of quality with respect to the key product parameters. Such analyses are performed at two levels. First, a macro, or global, capacity study is undertaken using discrete or attribute data. This establishes the overall process by expressing process performance in σ units and C_p. In addition, such indices provide a means to benchmark the process under consideration against like processes. When this is done, more informed process engineering decisions can be made with regard to future process design efforts. Should the outcomes of the macro capability study provide undesirable result, a micro analysis is undertaken. Basically, a micro analysis involves stratifying the product quality data using Pareto diagrams in order to prioritize subsequent optimizations efforts during phase three. Also, it is possible that at this point, there may be a need for collecting continuous data at the variable or "knob" level so that such things as " parameter control efficiency" can be assessed in relation to the 6σ model.

Third Phase, Improve phase, is related to the optimization of those characteristics identified during the micro capability study. The intent here is to improve quality performance by reducing the influence of the underlying cause system. This is accomplished by deriving realistic operating tolerances for the "vital few" variables within the cause system. To do this, the engineer must first determine which variables, as related to the key process steps, are "leverage" in nature. In other words, the engineer must first determine which of the factors are variation sensitive. Such identification is most often accomplished through the use of multi-vari charts, statistical graphs, brainstorming techniques, fractional factorial experiments, Taguchi style arrays, etc. In short, the tools of statistical process control (SPC) are applied to track down the sources of product and process variation.

Next, the functional limits (LFL and UFL, respectively) must be defined for each of the vital few factors. Usually this is accomplished with statistically designed experiments such as full factorial and response surface matrices. The reason for this is in order to adequately improve a process, existing nonlinear and interactive effects must be surfaced in order to know how to best prescribe settings for the critical process parameters. One must be able to take advantage of such things if improve is to occur. The classical one factor-at-a-time approach will not do. This approach is inefficient and cost prohibitive and often not capable of surfacing optimum conditions. The end result of this step is a set of "predictions limits" for each of the vital few variables. In other words, the optimization experiments allow the required functional limits, or realistic tolerance, to be defined such that a product characteristic behaves to desired.

Following this step, the engineer must match the new performance capability related to the vital few factors to the 6σ performance model. This step is most often achieve by comparing real time performance data, normally displayed in the form of a histogram, to the experimentally defined realistic tolerance width. If the +/-3σ range of histogram only consumes 50 percent of the realistic tolerance, then the variable would be said to be "capable of 6σ control". Given this condition, $C_p = 2.0$. If $C_{pk} < 1.5$, then the variable would be expended to adjust the parameter mean back on the target such that $C_{pk} > 1.5$. If this is done, then one would expect the parameter to exceed the UFL and LFL only 3.4 times, or fewer, out of every 1,000,000 manufacturing cycles, assuming a cause system that exhibits typical shift and drifts.

If the criteria for 6σ capability is not met by this point in time, the engineer has three choices which are:

1. Track down and eliminate the sources of variation if the parameter displays a great deal of nonrandom variation, assuming it would be economical to do so.
2. Replace or otherwise modify the technology if the parameter does not meet the criteria but is free of " assignable causes".
3. Alter the process to " desensitize" the critical variables, therein allowing the functional limits (UFL and LFL) of those variables to be redefined such that the +/-6σ limits of the natural process distributions are compatible with their respective realistic tolerances. In this sense, the 6σ manufacturing model would be achieved by

- Desensitizing the leverage factors.
- Establishing guardbands on those factors which still exhibit a moderate form of leverage.
- Opening the functional limits of the "trivial many" factors which are relative noninfluential.

A manufacturing strategy along these lines is far more efficient, not to mention more cost effective, than simply "guardbanding and automating everything in sight". Obviously, a fourth option would involve some combination of the alternative just mentioned.

Forth Phase, Control phase, is most tied to the classical uses of SPC – parameter monitoring and control. Once the vital few variables have boon optimized, they must be controlled within their realistic tolerances. If this is not done, the attribute control charts associated with the product performance characteristics will display unfavorable variation, In this sense, the charts will signal the alarm when a problem is about the surface. As may be apparent, the primary issue related to this phase is one of a prior control – discovering signs of future problems and correcting them before they occur.

3.2 Time study[4]

3.2.1 Introduction

Time study is a techniques of establishing an allowed time standard for performing a given task, based on measurement of the work content of the prescribed method, with due allowance for fatigue and for personal and unavoidable delays. The objective of time study is to determine reliable standards for all work, both direct and indirect, being under taken by the enterprise for the efficient and effective management of the operation.

With reliable time standards, capacity in terms of anticipated output, can be determined of equipment and facilities. Work can be scheduled so as to maximize output over time, thus obtaining high utilization of both labor and equipment. A system of variance reporting can be introduced thus simplifying good management. Management can investigate the different between actual and standard times and take appropriate action where necessary

Standard times facilitate methods engineering. Since time is a common measure for all jobs, time standards are a basis for comparing various methods of doing the same piece of work. Standard times provide a basis for purchasing the most productive new equipment. They provide the means for introducing sound production control. Furthermore, standard times serve as a means of securing and efficient layout of the available space. Since time is the basis of determining how much of each kind of equipment is needed, accurate time standards provide a means of balancing the work force with the available work.

A further objective of the development of reliable time standards is to initiate the procedure of accurate cost determining in advance production.

Other good management practices that may be enhanced with the application of measured time standards include budgetary control, the development of supervisory bonuses, and the ensuring of the maintenance of quality requirements.

3.2.2 Definition of Time study

Time study is used to determine the time required by a qualified and well-trained person working at the normal pace to do a specified task. It should be noted that, whereas motion study is largely design. time study involves measurement. Time study is used to measure work. The result of time study is the time that a person suited to the job and fully trained in the specified method will need to perform the job if he or she works at a normal or standard tempo. This time is called the standard time for the operation.

3.2.3 Uses for Time study

Although time study originally had its greatest application in connection with wage incentives, it and the other methods of measuring work are now used for many other purposes including:

1. Determining schedules and planning work.
2. Determining standard costs and as an aid in preparing budgets.
3. Estimating the cost of a product before manufacturing. Such information is of value in preparing bids and in determining selling price.

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[4] Salvendy G. Handbook of Industrial Engineering. United States of America: John Wiley&Sons 1992

4. Determining machine effectiveness, the number of machines which one person can operate, and as an aid in balancing assembly lines and work done on a conveyor.
5. Determining time standards to be used as a basis for the payment of wage incentive to direct labor and indirect labor.
6. Determining time standards to be used as a basis for labor cost control.

3.2.4 Time study equipment

The equipment needed for time study work consists of a timing device and an observation board. The devices most commonly used for measuring work are:

1. Stopwatch or electronic timer
2. Motion picture camera(with constant-speed motor drive)
3. Electronic data collector and computer
4. Electrical and mechanical time recorders
5. Observation board

3.2.5 Making the time study

The exact procedure used in making time studies may vary somewhat, depending upon type of operation being studied and the application that is to be made of the data obtained. These eight steps, however, are usually required:

1. Secure and record information about the operation and operator being studied.
2. Divided the operation into elements and record a complete description of the method.
3. Observe and record time taken by the operator.
4. Determine the number of cycles to be timed.
5. Rate the operator's performance.
6. Check to make certain that a sufficient number of cycles have been timed.
7. Determine the allowances.
8. Determine the time standard for the operation.

3.2.6 Is the job ready for time study?

After a request for a time study has been received by the time study department and an analyst has been assigned to make the study, he or she should go over the job with the supervisor of the department. As they discuss each element of the operation, the analyst asked the question, "Is this operation ready for a time study?"

The time standard established for a job will not be correct if the method of doing the job has changed, if the materials do not meet specifications, if the machine speed has changed, or if other conditions of work are different from those that were present when the time study was originally made. The time study analyst therefore examines the operation with the purpose of suggestion any changes that he or she thinks should be effected before the time study is made.

Although the supervisor may have set up the job originally or may have checked the method with the process engineer who set it up, the time study analyst should question each phase of the work, asking such question as:

1. Can the speed or feed of the machine be increased without affecting optimum tool life without adversely affecting the quality of the product?
2. Can change in tooling be made to reduce the cycle time?
3. Can material be moved closer to the work area to reduce handling time?
4. Is the equipment operating correctly, and is a quality product being produced?
5. Is the operation being performed safely?

It is expected that the time study analyst will be trained in motion study and will bring all possible knowledge in this field to bear on the operation about to be suited. Any suggested changes that the supervisor wishes to adopt should be made before the study is started. The supervisor of course makes the decision as to the way the job is to be done, but the analyst and the supervisor should discuss each element of the operation and should agree that the operation is ready for time study.

If the major change in the operation is to be made and if considerable time will be required to put the new method into effect. It might be wise to make a time study of the present method and then, after the improvement are installed, restudy the job and set a new time standard. If only minor changes are contemplated, it is usually advisable to complete such changes before making a time study of the job.

Those phases of time study that can be carried out at the time and place of the performance of the operation will be described. They are obtaining and recording necessary information, dividing the operation into subdivisions or elements, listing this elements in proper sequence, timing them with the stop watch and recording the ratings, determining the number of cycles to be timed, recording the operator's tempo or performance level, and making a sketch of the part and of the work place.

3.2.7 Recording information

All information requested in the heading of the observation sheet should be carefully recorded. This is important because times studies hastily and incompletely made are of little value. The first place to practice thoroughness is in filling in all necessary information for identification. Unless this is done, a study may be practically worthless as a record or as a source of information for standard data and formula construction a few months after it has been made, because the person who made the study has forgotten the circumstances surrounding it. Ordinarily, the necessary information concerning the operation, part, material, customer order number, lot size, etc., can be obtained from the route sheet, bill of material, or drawing of the part.

A sketch of the part should be drawn at the bottom or on the back of the sheet if a special place is not provided. A sketch of work place should also be included, showing the working position of the operator and the location of the tools, fixtures, and materials. Specifications of the materials being work on should be given, and a description of the equipment being used should be recorded. Ordinarily the trade name, class, type, and size of the machine are sufficient description. If the machine has an identification number assigned to it, the number should be included. Accurate record should be made of the number, size, and description of tools, fixtures, gauges, and templates. The name and number of the operator should be recorded, and the time study should be signed by the time study analyst.

3.2.8 Dividing the operation into elements and recording a description of the method

The standard time for an operation applies only to that particular operation; therefore, complete and detailed description of the method must be recorded on the observation sheet or on auxiliary sheets to be attached to the observation sheet. The important of this description can not be over emphasized. At any time the standard has been established for a job, the time study department may be asked to determined whether the operator is performing the job in the same way it was being performed when the time study was originally made. The information contained on the observation sheet is the most complete description of the method that the time study department has available for such a check.

3.2.9 Reason for element breakdown

Timing an entire operation as one element is seldom satisfactory, and an over-all study is no substitute for a time study. Breaking the operation down into short elements and timing each of them separately are essential parts of time study, for the following reason:

1. One of the best ways to describe an operation is to break it down into definite and measurable elements and describe each of these separately. Those elements of the operation that occur regularly are usually listed first, and then all other elements that are a necessary part of the job are

described. It is sometimes desirable to prepare a detail description of the elements of an operation on a separate sheet and attach it to the observation sheet.

2. Standard time values may be determined for the elements of the job. Such element time standards or standard data make it possible to determine the total standard time for an operation
3. A time study may show that excessive time is being taken to perform certain element of the job or that too little time is being spent on other elements. This latter condition sometimes occurs on inspection elements. Also the analysis of an operation by elements may show slight variation in method that could not be detected so easily from an over-all study.
4. An operator may not work at the same tempo throughout the cycle. A time study permits separate performance rating to be applied to each element of the job.

When time studies are to be made of a new product or a new type of work, a careful analysis should be made of all variation of the work that are likely to occur. It is desirable to establish standard data as soon as possible and such standards can be develop more quickly if the general framework of the standards is prepared before any time studies are made. It is especially important to prepare a definition of elements so that these same elements may be used in all time studies.

3.2.10 Rule for dividing an operation into elements

All manual work may be divided into fundamental had motions or therbligs, as has already been explained. These subdivisions are to short in duration to be timed with a stopwatch. A number of them, therefore, must be grouped together into elements of sufficient length to be conveniently timed. Three rules should be followed in dividing an operation into elements:

1. The elements should be as short in duration as can be accurately timed.
2. Handling time should be separated from machine time.
3. Constant elements should be separated from variable elements.

To be of value a time study must be a study of the elements of the operation, not merely a record of the total time required per cycle to do the work. If elements are too shot, however, it is impossible to time them accurately.

In machine work it is desirable to separate the machine time, that is, the time that the machine is doing work, from the time during which the operator is working. There are several reasons for this. Where power feeds and speeds are used on the machine, it is possible to calculate the time require for the "cut" and thus check the actual stop-watch data when the machine time is kept separately. Also, the beginning and end of the cut are excellent beginning and ending points for an element. Where standard data and formulas are to be developed, it is essential that machine time be separated from handling time.

The elements of cycle that are constant should be separated from those that are variable. The term constant elements refer to those elements that are independent of the size, weight, length, and shape of the piece. For example, in soldering is a constant, whereas the time to solder the side seam on the can is a variable, varying directly with the length of the seam.

The analyst trained in the micro motion study technique or in the use of predetermined times will find it relatively easy to decide upon the elements of the operation, because they are merely combinations of fundamental motions. The analyst without such training should wee that the elements begin and end at well-defined points in the cycle. These points will have to be memorized so that the analyst will always read his watch at exactly the same place in the cycle; otherwise the time for the elements will be incorrect.

Each element should be concisely recorded in the space provided on the sheet. It is sometimes advisable to use symbols to represent elements that are often repeated. In some industries a standard code of symbols, is used by all time study observers. When symbols are used, their meaning should appear on each observation sheet. (Barnes, 1980)

3.2.11 Determining the number of cycles to study

Time study is a sampling procedure. As such, it is important that an adequate-sized sample of data be collected so that the resulting standard is reasonably accurate.

From an economic standpoint, both the duration of the cycle and the activity of the work need to be considered in determining number of cycle to be observed. Table 3.1 can serve as a guide to determining the number of cycles that should be studied in order to ensure and adequate sample may be determined statistically.

Cycle Time	Minimum Number of cycles to study for given activity			
	More than 10,000/year	5000 to 10,000/year	1000 to 5000/year	Less than 1000/year
More than 60 min	6	5	4	3
40 to 60 min	8	7	6	5
20-40 min	10	9	8	7
10 to 20 min	12	11	10	9
45 to 10 min	20	18	16	15
2 to 5 min	25	22	20	18
1 to 2 min	40	35	30	25
Less than 1 min	60	50	45	40

Table 3.1 Number of cycles required for a time study

The work sampling method uses and estimation procedure which provides accurate data on operating conditions from results of spot observation made on motions of various machines and operators at predetermined times.

3.2.12 Kinds of work sampling methods

Work sampling methods include the following techniques

a) Simplified sampling method(Regularly ordered interval sampling)

b) Random sampling method

The random sampling method is the most popular and widely uses method.

1. Equations for work sampling

For work sampling, reliability factor of 95%(2σ) is used except when otherwise required. Reliability of 95% means that 95% of the data obtained from random observations tell the truth. Assuming reliability to 95% and tolerance to be E, the following equation can be derived:

$$E = 2\sigma = 2\sqrt{\frac{P(1-P)}{N}} \qquad \text{(1)}$$

This equation signified that means value P obtained from N number of samples lies within the range of true value, plus or minus E, with a liability factor of 95%. That is, the true value exists somewhere in the region of P plus or minus E. The tolerance expressed here by E is called absolute error.

To indicate the proportion of absolute error E to mean value S, the following equation is used:

$$S = \frac{E}{P} = 2\sigma\sqrt{\frac{(1-P)}{NP}} \qquad \text{(2)}$$

where, E : Absolute error

S : Desired relative accuracy (or relative error)

P : Percentage occurrence of a delaying activity

σ : Standard deviation of binomial distribution

N : Total number of random observations(Random sample sizes)

$$N = \frac{4(1-P)}{S^2 P} \qquad \text{.........................} \qquad (3)$$

Equation(2) is converted as follows for easy calculation:

From equation (3), the required number of random observations can be obtained.

3.2.13 Practical of work sampling

1. Determine the number of samples necessary to obtain sufficient estimation accuracy

   - Population must be one
   - Required number of samples N

$$N = \frac{4P(1-P)}{e^2}$$

P: Non-work ratio during preliminary observation.

e : error

1. Method of Work sampling

Step 1: Listing and classification of observation items

Step 2: Preliminary sampling, estimation of P

Step 3: Required number of samples, calculation of N

Step 4: Actual planning: Number of days required, observation intervals, worksheet preparation

Step 5: Plan implementation

Step 6: Aggregation

Step 7: Review, improvement of program planning

2. Practice of Work sampling

Cargo handling site, worker: 6

3. Results of preliminary survey

Number of observations: 15 rounds x 6 workers = 90 sampling

Working: 75%

Partially working: 15%

Non-working: 10%, P = 10%

4. Action plan

Number of required samplings

$$N = \frac{4P(1-P)}{e^2}$$

$$= \frac{4 \times 0.1 \times (1-0.1)}{(0.05)^2}$$

$$= 144$$

Number of samplings required from this moment = 144-90

= 54 samplings

Number of required rounds: 54 samplings/6 = 9 times

(Taniguchi, 1989)

3.3 Line balancing

3.3.1 Product-oriented layout

Product-oriented layouts are organized around a product or a family of similar high volume, low variety product. Product-oriented layouts. The assumptions are:

1. Volume is adequate for high equipment utilization.
2. Product demand is stable enough to justify high investment in specialized equipment.
3. Product is standardized or approaching a phase of its life cycle that justifies investment in specialized equipment.
4. Supplies of raw material and components are adequate and of uniform quality (adequately standardized) to ensure that they will work with the specialized equipment.

Two types of a product-oriented layout are a fabrication line and assembly line. The fabrication line builds components, such as automobile tires or metal parts for refrigerator, on a series of machines. An assembly line puts the fabricated parts together at a series of workstations. Both are repetitive processes, and in both cases, the line must be "balanced." That is, the work performed on one machine must balance with the work performed on the next machine in the fabrication line. As the work done at one workstation by an employee on an assembly line must match up in time with the work done at the next workstation by the next employee.

Fabrication line tend to be machined-paced and required mechanical and engineering changes to facilitate balancing. Assembly lines, on the other hand, tend to be paced by work tasks assigned to individuals or to workstations. Assembly lines, therefore, can be balanced by moving tasks from one individual or station is equalized.

The central problem in product-oriented layout planning is to balance the output at each workstation on the production line so that it is nearly the same, while obtaining the desired amount of output. Management's goal is to create a smooth continuous flow among the assembly line with a minimum of idle time at each person's workstation.

A well-balanced assembly line has the advantage of high personnel and facility utilization and equity between employee's workloads. Some union contracts include a requirement that workloads must be nearly equal among those on the same assembly line. The term most often used to describe this process is **assembly line balancing**. Indeed, the *objective of the product-oriented lay out is to minimize imbalance in the fabrication or assembly line*.

The main advantage of product oriented layout is the low variable cost per unit usually associated with high-volume, standardize products. The product-oriented layout also keeps material handling cost low, reduces work in process inventories, and make training and supervision easier. These advantages often outweigh the disadvantage of product layout. These advantage are as follow:

1. High volume is required because of the large investment needed to set up the process.
2. Work stoppage at any one point ties up the whole operation.
3. There is a lack of flexibility in handling a variety of product or production rates.

Because the problems of fabrication lines and assembly lines are similar, we phrase our discussion in terms of an assembly line. On an assembly line, the product typically moves via automated means, such as a conveyor, through a series of workstations until completed.

3.3.2 Assembly line balancing

Assembly is a process of putting parts together. A critical factor is the sequence. If the wrong sequence is chosen, the process may end with some part left over, as in the case of an amateur who took apart a grand father clock and then tried to put it back together. The sequence for assembling part determines whether the product will perform after its assembly is complete.

Thus, the first step in assembly line balancing is to define the assembly task sequences that must be followed in strict order. Assembling each component part is a task element of the assembly process. However, the sequence of many task elements is not strictly ordered, and alternative sequences define alternative methods for assembling the product. The process of assembly line balancing is to examine and compare these alternative methods using criteria for a perfectly balanced assembly line. These criteria are: that the work cycle times for all workstations on the line be nearly equal as practicable; that there be a minimum of idle (non productive) time for the assembly line; and that assembly rates are at least equal to demand rates. (Chen and McGarrah, Productivity Management Text&Cases)

Line balancing is usually done to minimize imbalance between machines or personnel while meeting a required out from the line. To balance a line, management must know the tools, equipment, and work methods used. Then the time requirements for each assembly task (such as drilling a hole, tightening a nut, or spray printing a part) must be determined. Management also needs to know the precedence relationship among the activities, that is, the order in which various tasks need to be performed.

Example 3.1 Show how to turn these task data in to precedence diagram.

We want to develop a precedence diagram for an electronic copier that required a total assembly time of 66 minutes. Table 3.2 and Figure 3.4 give the tasks, assembly times and sequence requirements for the copier

Task	Performance time (Minutes)	Task must follow task list below
A	10	-
B	11	[illegible]
C	5	B
D	4	B
E	12	A
F	3	C,D
G	7	F
H	11	E
I	3	G,H
Total time	66	

This mean that task B and E can not be done until task A has been complete

Table 3.2 Precedence data

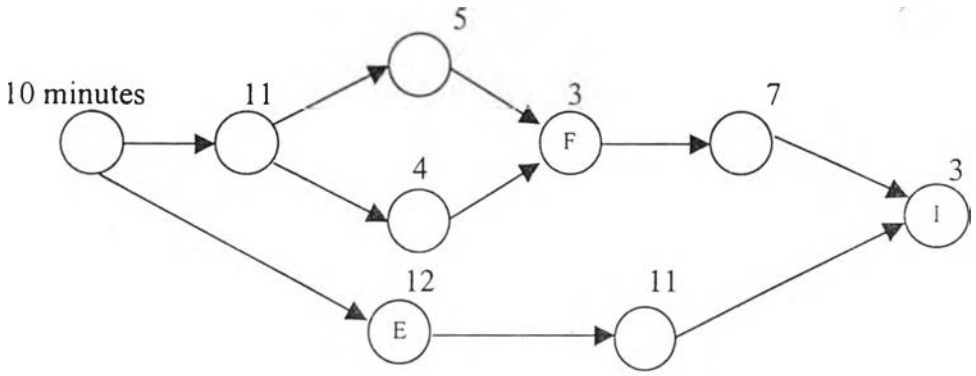

Figure 3.4 Precedence Diagram

Once we have construct the precedence chart summarizing the sequences and perform times, we turn to the job of grouping tasks into job station to meet the specified production rate. This process involves three steps:

1. Take the demand (or production rate) per day and divide it into the productive time available per day (in minutes or seconds). This operation give up the cycle time, namely, the time the product is available at each work station:

$$\text{Cycle time} = \frac{\text{Production time available per day}}{\text{Demand per day or production per day}}$$

2. Calculate the theoretical minimum number of workstations. This is the total task-duration time divided by the cycle time. Fraction are rounded to the next higher whole number:

$$\text{Minimum number of workstations} = \frac{\text{Summation time for task i}}{\text{Cycle time}}$$

3. Perform the line balance by assigning specific assembly task to each workstation. An efficient balance is one that will complete the required assembly, follow the specified sequence, and keep the idle time at each workstation to a minimum. A formal procedure for doing this is:

(a) Identify a master list of work elements and separate the available work elements from the unavailable work elements.

(b) Eliminate those work elements that have been assigned.

(c) Eliminate those work elements whose precedence relationship has not been satisfied.

(d) Eliminate those elements for which there is inadequate time available at the workstation.

(e) Identify a unit of work that can be assigned, such as the first unit of work in the list, the last unit of work in the list, the unit of work with the shortest time, the unit of work with the longest time, a random selected unit of work, or some other criterion.

(f) Switch the work elements to find the best balance available

Example 3.2 illustrates a simple line balancing procedure.

On the basis of the precedence diagram and activity times given in example 3.2, the firm determines that there are 480 productive minutes of work available per day. Furthermore, the production schedule requires that 40 units be completed as output from the assembly line each day. Hence,

$$\text{Cycle time (in minutes)} = \frac{480 \text{ minutes}}{40 \text{ units}}$$

$$= 12 \text{ minutes/unit}$$

$$\text{Minimum number of workstations} = \frac{\text{Total task time}}{\text{Cycle time}}$$

$$= \frac{66}{12}$$

$$= 5.5 \text{ or } 6 \text{ stations}$$

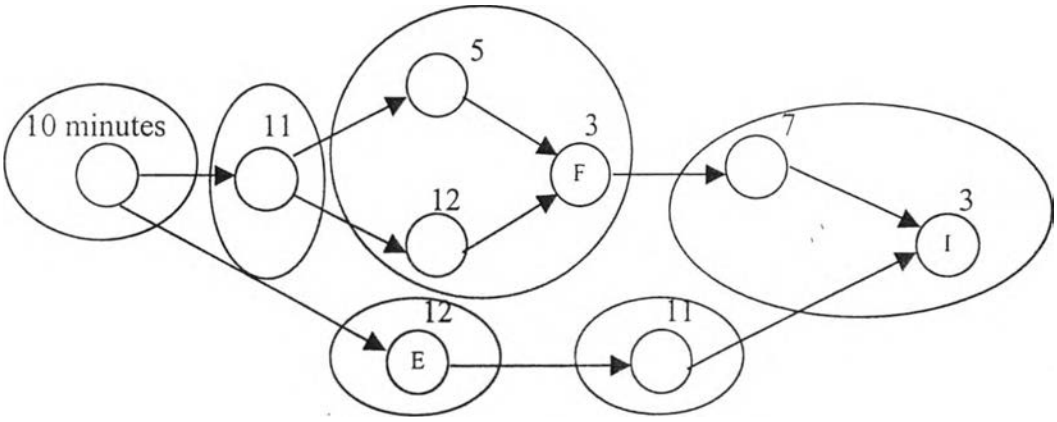

Figure 3.5 Precedence diagram (Solution)

Figure 3.5 Shows one solution that does not violate the sequence requirements and in which the tasks are grouped into six stations. To obtain this solution, appropriate activities were moved into workstations that use as much of the available cycle time of 12 minutes as possible.

The first workstation consumes 10 minutes and has an idle time of 2 minutes, the second workstation uses 11 minutes, and the third consumes the full 12 minutes. The fourth workstation groups three small tasks and balances perfectly at 12 minutes. The fifth has 1 minute of idle time, and the sixth (consisting of tasks G and I) has 2 minutes of idle time per cycle. Total idle time for this solution is 6 minutes per cycle. . (Heizer and Render, 1996)

3.4 Standard UPH

3.4.1 Time Study Form

All the detail of the study are recorded on the time study form. To date, little standardization in design of forms used by various industries has taken place. The form must provide space to record all pertinent information concerning the method being studied. This is often done by constructing an operator process chart on one side of the form. In additional to making a permanent record of the relative location of the tools and materials in the work area, analyst can list such methods data as feeds, depths of cuts, speeds, and inspection specifications. Of course, analysts should identify the operation being studied by including such information as the operator's name and number, operator description and number, machine name and number, special tools used and their respective number, department where the operation is performed, and prevailing working conditions. Providing too much is better than too little information concerning the job being studied.

The time study form should also include space for the signature of the supervisor, indicating approval of the method under observation. Like wise, the inspector should sign every study taken, acknowledging his or her acceptance of the quality of the parts being produced during the time study.

Analyst should design the form so that it contain watch readings foreign elements, and rating factors, and still has space to calculate the allowed time.

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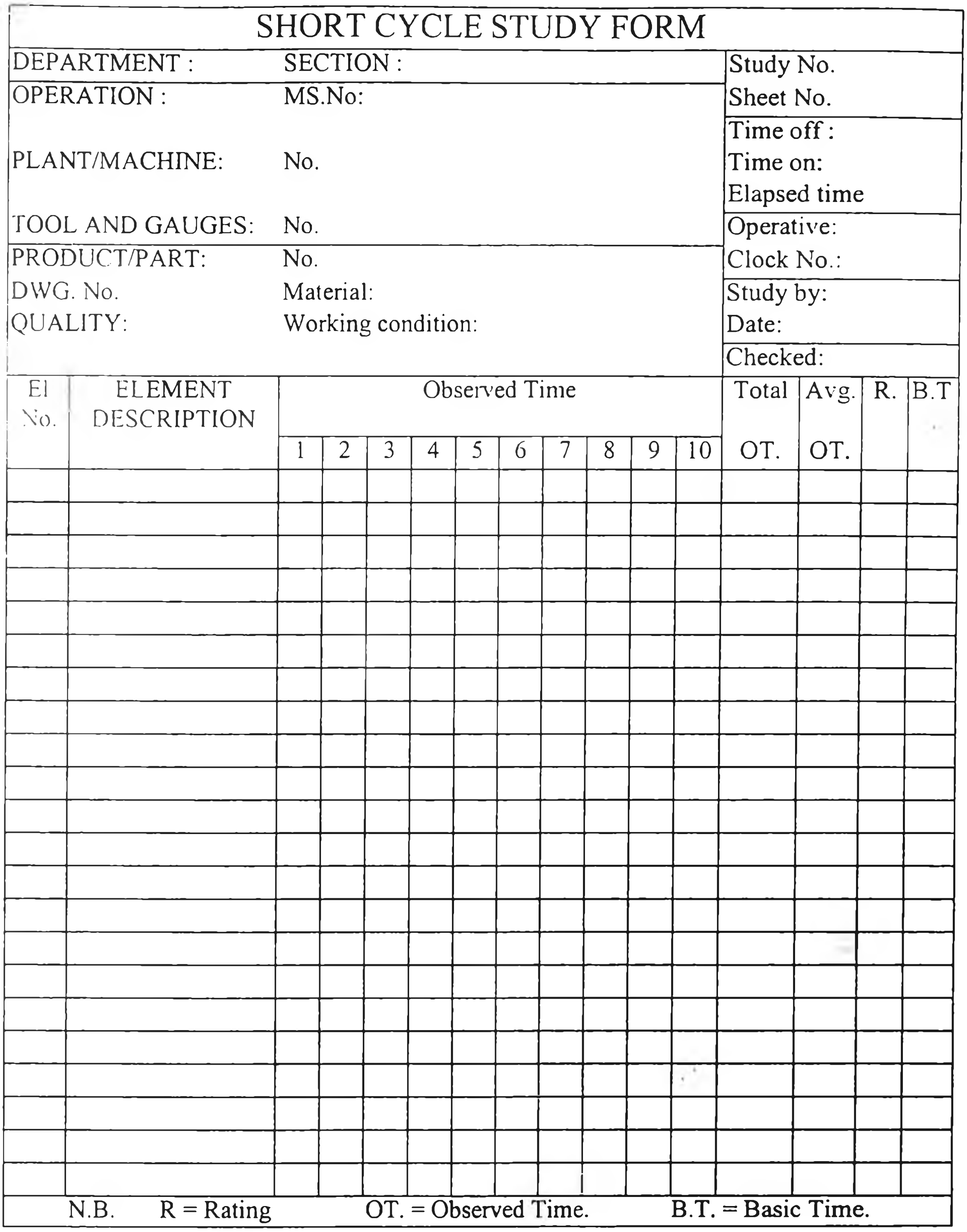
[4] Time Study references from Neibel, B W. "Motion and Time Study".



SHORT CYCLE STUDY FORM

DEPARTMENT :	SECTION :	Study No.
OPERATION :	MS.No:	Sheet No.
		Time off :
PLANT/MACHINE:	No.	Time on:
		Elapsed time
TOOL AND GAUGES:	No.	Operative:
PRODUCT/PART:	No.	Clock No.:
DWG. No.	Material:	Study by:
QUALITY:	Working condition:	Date:
		Checked:

El No.	ELEMENT DESCRIPTION	Observed Time										Total	Avg.	R.	B.T
		1	2	3	4	5	6	7	8	9	10	OT.	OT.		

N.B. R = Rating OT. = Observed Time. B.T. = Basic Time.

Figure 3.6 Simple type of short cycle time form (รศ.ดร.วิจิตร ตัณฑสุทธิ์, พ.ศ.2524)

3.4.2 UPH Calculation

From the observation sheet, after Industrial engineer observed work element from the production line and do the motion and time study or work study. They can conclude like this:

UPH means the capacity rate per hour or amount of units that produced from production line per hour.

$$1 \text{ Hour} = 1 \text{ Hour} \times 60 \frac{\text{Minutes}}{\text{Hour}} \times 60 \frac{\text{Seconds}}{\text{Minutes}}$$

$$= 3600 \text{ Seconds/Hour.}$$

$$\text{UPH} = \frac{3600 \text{ Seconds}}{\text{Standard time}}$$

For example, calculated UPH of Load head operation, Gimbal bond operation and Flex bond operation.

From the standard time on Figure 4.4

At Load head operation, UPH = 3600/10.59

= 340 units/hour.

At Gimbal bond operation, UPH = 3600/18.46

= 195 units/hour.

At Flex bond operation, UPH = 3600/17.65

= 204 units/hour.

Item No.	Description operation	Standard time (Sec.)	UPH
1	MRB screen		
2	Pre-trim	4.30	662
3	Load head	10.59	340
4	Gimbal bond	18.46	195
5	Flex bond	17.65	204
6	Lead bond	18.46	195
7	Lead coat	9.68	372
8	Tail tack	13.48	267
9	Survelliance#1	20.81	173
10	Oven profile		
11	Unload Jit tool	9.42	382
12	Load IAT test arm	9.68	372
13	Pin flex & Spot clean	21.80	165
14	Surveillance#2	20.81	160
15	Head set	6.15	585
16	Pre-load	22.64	159
17	RSA/PSA	20.00	225
18	Trim shunt tab	4.14	870
19	MRE check	12.41	293
20	Fly test	80.00	45
21	Electrical test	37.89	95
22	Flex shunting	6.87	437
23	Unload IAT & Fold flapper	10.88	327
24	Final inspection	21.18	128
25	QC	28.13	128
26	Packing	2.40	1500

Table 3.3 Cheetah18 UPH and Standard Time

3.4.3 Capacity rate[5]

Capacity is defined as the maximum output of a system in a given period under ideal conditions. In a process-focus facility, capacity is often determined by some measure of size such as the number of beds in a hospital or seating capacity in a restaurant. In a repetitive process the number of units assembled each shift, such as number of refrigerators, may be the criterion for capacity. And in a product-focused facility, such as Nucor, tons of steel processed per shift may be the measure of capacity. Whatever that measure, the capacity decision is critical to an organization because everything from cost to customer service depends upon the capacity of the process.

Many organizations operate their facilities at a rate less than capacity. They do so because they have found that they can operate more efficiently when their resources are not stretched to the limit. Instead, they operate at perhaps 92% of capacity. This concept is called effective capacity, or utilization. Effective capacity, or utilization, is simply the percent capacity expected. It can be computed from the following formula:

$$\text{Effective capacity, or utilization} = \frac{\text{Expected capacity}}{\text{Capacity}}$$

Effective capacity, or utilization, is the capacity a firm can expect to achieve given its product mix, methods of scheduling, maintenance, and standards of quality.

Another capacity consideration is efficiency. Depending on how facilities are used and managed, it may be difficult or impossible to reach 100% efficiency.

Typically, efficiency is expressed as a percentage of the effective capacity. Efficiency is a measure of actual output over effective capacity:

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}}$$

The rated capacity is a measure of the maximum usable capacity of a particular facility. Rated capacity will always be less than or equal to the capacity. The equation used to compute rated capacity is

$$\text{Rated capacity} = (\text{capacity})(\text{utilization})(\text{efficiency})$$

- Cheetah18 capacity rate calculation

Assume that, the company has 21 working hour per day and 90% efficiency.

$$\text{Capacity rate} = \left(\text{Amount of } \frac{\text{units}}{\text{Hour}}\right) \times \left(21 \, \frac{\text{Hours}}{\text{Day}}\right) \times (90\% \text{ efficiency})$$

$$= (\text{UPH}) \times (21) \times (90\% \text{ efficiency})$$

At Load head operation, capacity rate/ 1Opr = (340 x 21 x 0.9)

= 6426 units/day.

At Gimbal bond operation, capacity rate/ 1Opr = (195 x 21 x 0.9)

= 3686 units/day.

At Flex bond operation, capacity rate/ 1Opr = (204 x 21 x 0.9)

= 3856 units/day.

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[5] Capacity Rate references from Heizer J., and Render B. "Production and Operation Management Strategic and Tactical Decisions".

3.4.4 Line balancing, Head count requirement calculation

For the head count that required for production line. There are 8 main factors that effect to the calculation.

1. Line loading per day or raw material input per day.
2. Amount of working hour per day.
3. % efficiency of production line
4. Process electrical yield.
5. Process mechanical yield.
6. % Sampling or % input per each operation.
7. Space requirement per operation
8. Space limitation.

To explain, the manufacturing head gimbal bond factory, which is the heart of recording storage on hard disk drives, has 9.9K line loading per day or loaded with 9,900 units of raw material.

At load head operation;

$$\text{Head count required} = \frac{\text{Line loading per day}}{\text{Capacity-operation per day}}$$

$$= \frac{\text{Line loading per day}}{(\text{UPH})\text{x}(\text{Working hour/day})\text{x}(\%\text{ efficiency})}$$

$$= \frac{9{,}900(\text{units/day})}{340(\text{units/hr}) \text{ x } 21(\text{hours/day}) \text{ x } 90(\%\text{ efficiency})}$$

$= 1.54$ Operators/line

~ 2.0 Operators/line

From the calculation, with 10.9K line loading or 10900 units of raw material that loaded in to production line for producing head gimbal bond of hard disk drive require 2 operators per line.

At Gimbal bond operation, head count required is

$$= \frac{10900(\text{units/day})}{195(\text{units/hr}) \times 21(\text{hours/day}) \times 90(\%\ \text{Efficiency})}$$

= 2.96 Operators/line

~ 3.0 Operators/line