

8.0 - Chapter Introduction

In this chapter, you will learn about work measurement concepts and their application to cost analysis.

Work Measurement. Work Measurement involves the use of labor standards to measure and control the time required to perform a particular task or group of tasks. Most often labor standards are developed and applied in manufacturing operations, however labor standards can be used in estimating and managing the cost of a vast variety of activities including engineering drafting, clerical administration, and janitorial services.

Work Measurement System. A Work Measurement System is a management system designed to:

- Analyze the touch labor content of an operation;
- Establish labor standards for that operation;
- Measure and analyze variances from those standards; and
- Continuously improve both the operation and the labor standards used in that operation.

Work Measurement System Plan. A Work Measurement System Plan is the firm's program for implementing, operating, and maintaining work measurement in its operations. It is the key to an effective Work Measurement System with a defined system clear responsibility assignments. As a minimum, the Plan should provide guidance on:

- Establishing and maintaining standard accuracy;
- Conducting engineering analyses to improve operations;
- Revising standards and related system data; and
- Using labor standards as an input to budgeting, estimating, production planning, and performance evaluation.

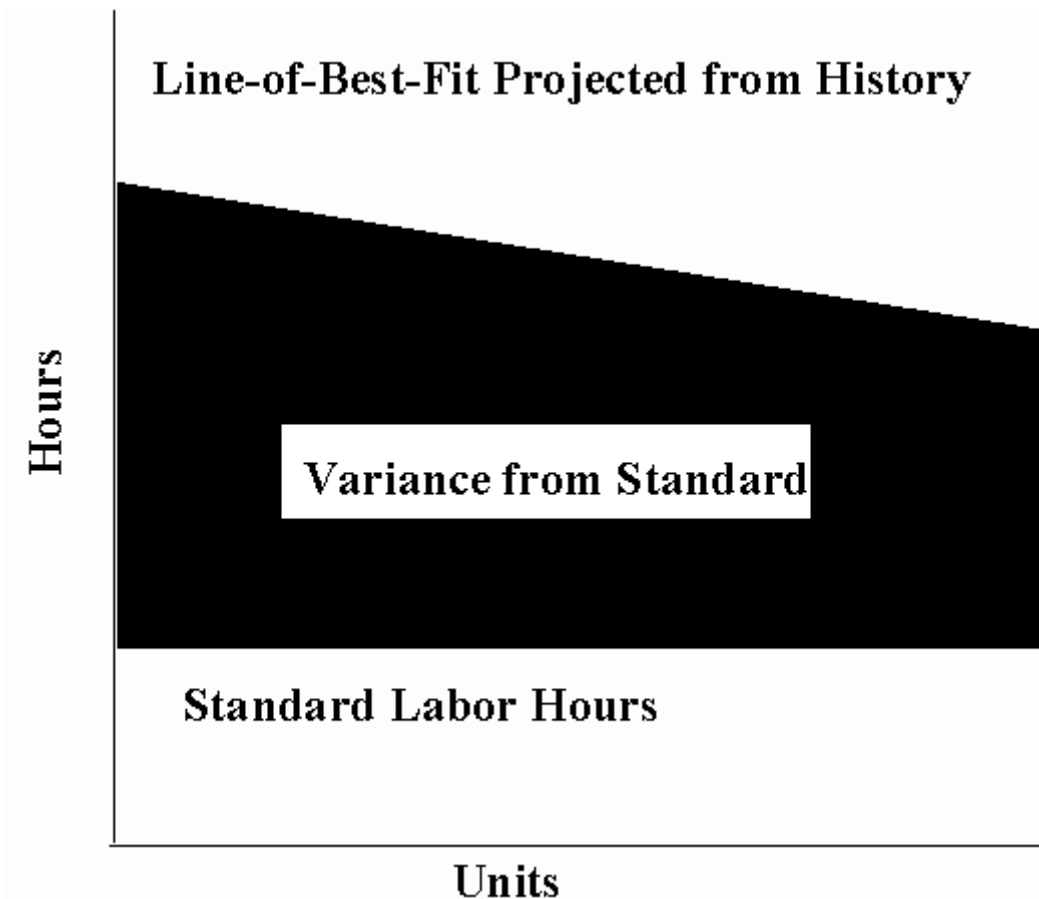
Labor Standard Types. A labor standard is a measure of the time it should take for a qualified worker to perform a particular operation. Labor standards are commonly grouped into two types:

- **Engineered standards** are developed using recognized principles of industrial engineering and work measurement. The standards developed define the time necessary for a qualified worker, working at a pace

- ordinarily used, under capable supervision, and experiencing normal fatigue and delays, to do a defined amount of work of specified quality when following the prescribed method. As a result, you can use engineered standards to examine contractor operations to estimate the number of labor hours that should be required to efficiently and effectively produce a particular product and to identify any projected contractor variances from that estimate.
- **Non-engineered standards** are developed using the best information available without performing the detailed analysis required to develop engineered standards. Historical costs are commonly used standards that typically measure the hours that have been required to complete a task rather than the hours that should be required.

Estimate of Efficient Operation Cost. Standards provide information on what it should cost to complete an operation or series of operations in product production. Instead of applying pressure to improve in all areas, managers can use this information to identify areas requiring particular management emphasis. The Acquisition Team can use that same information to identify inefficient operations for close scrutiny during contract negotiations.

- The log-log graph below presents a line-of-best-fit developed using actual labor-hour history. Note that this line follows the form of the improvement curve. Without labor standards, the firm and the Government would likely project the improvement curve to estimate the labor hours required to produce future units.



- Labor standards provide additional information that can be used in estimate development and analysis. The vertical distance between the labor-hour history and the labor standard represents the variance from the standard. Some of that variance may be related to inefficiencies that cannot be resolved. However, all elements should be targeted for identification and analysis. Key elements include:
 - Technical factors (e.g., manufacturing coordination, engineering design changes, fit problems, design errors, operation sheet errors, tooling errors, work sequence errors, and engineering liaison problems).
 - Logistics (e.g., incorrect hardware and parts shortages).
 - Miscellaneous factors (e.g., unusual working conditions, excessive overtime, and excessive fatigue).

- Worker learning (e.g., familiarity with processes and methods).
- Variance analysis should identify, categorize, and develop plans to control all variances from standard. Plans will typically concentrate on the operations with the largest variances from standard, because these operations present the greatest opportunity for cost reduction.

Updating Standards. Standards cannot be set and forgotten. Process improvement is one of the central elements of an effective Work Measurement System. As methods improve, the associated labor standards must be updated.

Standards changes will effect the estimating value of all the data based on those standards. For example, some variance analyses may remain valid while other analyses will be rendered meaningless as a result of the change. The System must assure that valid analyses are retained for continued utilization. At the same time, the System must also assure that meaningless data are not misused.

8.1 - Identifying Situations For Use

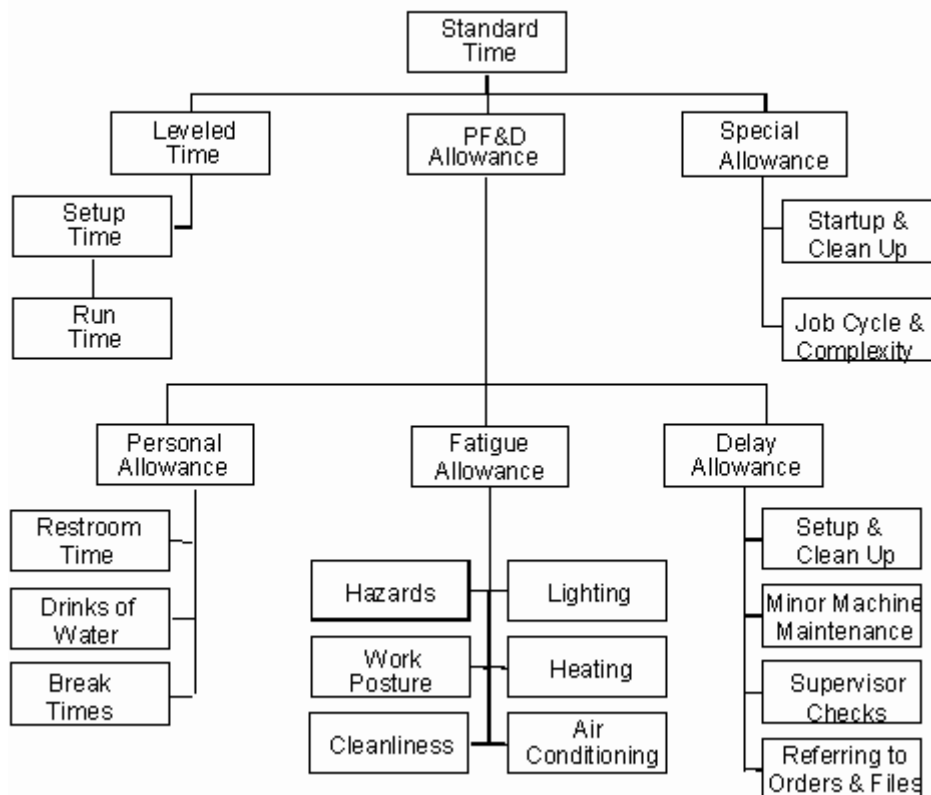
General Situations. Contractors should consider the use of labor standards whenever contractor employees will be performing the same tasks repetitively over an extended period of time. Labor standard development requires extensive detailed effort. The time and cost required for standards development are prohibitive unless the task will be performed repetitively. On the other hand, when an operation will be performed repetitively, the cost visibility provided by labor standards permits detailed cost evaluation and control, that can result in significant savings to the Government. To be of real value, labor standards must be considered in making key management decisions (e.g., budgeting, estimating, production planning, and performance evaluation).

8.2 Identifying Elements Of A Labor Standard

Key Elements. As a contracting officer, its likely that you will never be required to develop a labor standard.

However, you may be called upon to negotiate a contract price based, in part on labor standards. You should know the elements of a standard and how they are developed.

An engineered standard is composed of three elements: leveled time; a personal, fatigue, and delay (PF&D) allowance; and any applicable special allowances. The figure below depicts some of the factors that should be considered in each element.



Leveled Time. Leveled time is the time that a worker of average skill, making an average effort, under average conditions, would take to complete the required task. There are a variety of techniques used in leveled time development, but the four used most commonly are:

- **Time Study.** In performing a time study, industrial engineers (or other labor analysts) time the effort required to perform a defined task. While it may sound simple, this is a complex process that requires

special training and experience. To perform a time study, the analyst must:

- Clearly define and document the work design, including the best design of the work place, tools, tasks, and subtasks.
 - Select a person to be timed. The person selected should be receptive to being timed, experienced in the work methods being used, and familiar with the tasks and subtasks of the work design.
 - Observe and record the time that the selected worker requires to perform each of the subtasks in the work design. Several observations are required to average out random variations and assure that all elements of the work have been considered. The number of observations required will increase as the confidence level desired by the analyst increases and as the variability between observed times increases.
 - Assign a pace rating based on an evaluation of how the ability and effort of the worker being timed compares with those of an average worker. Using the pace ratings, the analyst converts observed times into a leveled time for the subtask.
 - Total subtask times to develop a leveled time for the entire task.
- **Predetermined Leveled Times.** Instead of using time study to develop a leveled time, the analyst can use predetermined leveled times (also called predetermined standards or basic motion standard data). Predetermined leveled times are established for basic body motions, such as reach, move, turn, grasp, position, release, disengage, and apply pressure. The analyst may obtain them from published standards in tabular or electronic forms, or the firm may develop its own. To use predetermined leveled times, the analyst must:
 - Clearly define and document the work design, including the best design of the work place, tools, tasks, and subtasks.
 - Select and document the source of the predetermined leveled times.
 - Identify and document the basic body motions involved in performing each subtask. Motions for each hand must be specifically identified. The need for precise measurement of complex body motions for each job element may make this method

of leveled time development inappropriate for complex tasks with long performance cycle times.

- o Assign times to the body motions required to complete each subtask and total assigned times to develop a leveled time for the subtask.

Documentation should demonstrate that the accuracy of the original data base has not been compromised in application or standard development.

- o Total subtask times to develop a leveled time for the entire task.

- **Standard Time Data.** Standard time data (or elemental standard data) are developed for groups of motions that are commonly performed together, such as drilling a hole or painting a square foot of surface area. Standard time data can be developed using time studies or predetermined leveled times. After development, the analyst can use the standard time data instead of developing an estimate for the group of motions each time they occur.

- o Typically, the use of standard time data improves accuracy because the standard deviations for groups of motions tend to be smaller than those for individual basic motions. In addition, their use speeds standard development by reducing the number of calculations required.

- o Estimate development using standard time data is much like using predetermined leveled times except that groups of motions are estimated as a single element instead of individual body motions.

- **Work Sampling.** Work sampling is commonly used to develop non-engineered standards. It cannot be used alone to develop engineered standards. However, it can be used to supplement or check standard development by more the definitive techniques described above. For example, it can be used to determine job content and assess productive vs. nonproductive time.

- o In work sampling, analysis is based on a large number of random, rather than continuous observations. Estimates are based the proportion of time spent by one or more persons on a given activity. This is useful for jobs with irregular components that vary in the amount of time per unit of output.

- o To use work sampling in standard development, the analyst must:

- Identify and define activities involved in the work (through discussions with the workers and preliminary observations).
- Develop the method(s) for observing and recording activities.
- Determine the sampling strategy (e.g., stratified) and number of observations (by time and place).
- Record observed activities during each period.
- Consolidate and analyze the data.
- Use the data collected to develop nonengineered standards or to supplement development of engineered standards.

PF&D Allowance ([DOD-5010.15-1-M, Basic Volume, App II](#)).

After the leveled time is developed, estimators must consider a personal, fatigue, and delay (PF&D) allowance. Be careful when contractors use predetermined time systems. Some predetermined time systems include a partial or complete allowance for PF&D. If the contractor uses such standards, additional PF&D consideration may not be appropriate.

Contractor work measurement policies and procedures should provide the detailed rationale used for applying PF&D allowances. Each allowance should be identified and quantified. Total PF&D allowances typically total 15 percent. However, allowances may be higher or lower depending on the nature of the work and related working conditions. For example, strenuous work in an extremely hot environment would typically merit a higher PF&D allowance than light labor performed in an air conditioned room.

- **Personal Allowance.** A personal allowance considers time for a worker to take care of personal needs, such as trips to the rest room and drinking fountain. The table below delineates some of the factors that should be considered.

Personal Allowance Considerations		
Personal allowance documentation should document:	Considerations	Typical Percentage Allowance
A Basic Allowance	Most firms allow, at	4.2

which considers the breaks available for work during an 8-hour day.	least, two 10-minute breaks during each 8-hour shift, the basic personal allowance is 4.2 percent (20 minutes/480 minutes).	
	Normal office conditions	0.0
	Normal shop, central heat, slightly dirty or greasy.	1.0
	<u>Slightly</u> disagreeable conditions. Exposed to inclement weather part of the time, poor heating, or poor cooling.	3.0
	<u>Extremely</u> disagreeable conditions. Proximity to hot objects, continuous exposure to disagreeable odors and fumes, or to excessive temperature ranges.	6.0
	Total time allowed:	
	5 minutes	1.0
	10 minutes	2.1
	15 minutes	3.1
	20 minutes	4.2
Any allowance for work performed in a super-clean room.	An additional allowance may be added to consider the time require to assure that super- clean room requirements are met.	4.0

- **Fatigue Allowance.** A fatigue allowance considers the time required to recuperate from fatigue. The table below outlines some of the factors that should be considered.

Fatigue Allowance Considerations

Personal allowance documentation should document:	Considerations	Typical Percentage Allowance
Any allowance for handling heavy weights.	<p>Effective Net</p> <p>Pounds Percent of Time Under Load</p> <p><u>Handled</u> <u>1-12</u> <u>13-25</u> <u>26-50</u> <u>51-75</u> <u>76-100</u></p> <p>1-10 0 1 2 3 4</p> <p>11-20 1 3 5 7 10</p> <p>21-30 2 4 9 13 17</p> <p>31-40 3 6 13 19 25</p> <p>41-50 5 9 17 25 34</p> <p>51-60 6 11 22 x x</p> <p>61-70 7 14 28 x x</p> <p>71-80 8 17 34 x x</p> <p>x - Study for possibilities for worker rotation and other means to relieve fatigue.</p>	Select percentage from table.
	<p>Multiply the table values above by the following factors to consider lifting requirements:</p> <p>For picking up from the floor, multiply the table value by 1.10.</p> <p>For placing the load above</p>	Depends on work.

	<p>chest height, multiply table value by 1.20.</p> <p>For getting the load from chest height, multiply the basic allowance by 0.50.</p>	
	<p>For sliding and rolling objects, multiply the weight by the coefficient of friction to determine the effective weight moved.</p> <p>Coefficients of Friction (Average Values)</p> <p><u>Surfaces Friction Coefficient</u></p> <p>Wood on Wood 0.4</p> <p>Wood on Metal 0.4</p> <p>Metal on Metal 0.3</p>	Depends on work.

Fatigue Allowance Considerations (cont)

Personal allowance documentation should document:	Considerations	Typical Percentage Allowance
	Sitting or standing. (Work will normally be less tiresome if the position is varied frequently.)	0.0
	Sitting.	1.0
	Walking.	1.0
	Standing.	2.0
	Climbing or descending ramps, stairs, or ladder.	4.0
	Working in close cramped quarters.	7.0

Any allowance for the mental requirements of the job.	Work largely committed to habit (e.g., simple calculations on paper, reading easily understood material, counting and recording, simple inspection requiring attention but little discretion, or arranging papers by letter or number).	0.0
	Work requires full attention (e.g., copying numbers or instructions, remembering part number while checking a parts list, or filing papers by subject of familiar nature).	2.0
	Work requires concentrated attention (e.g., reading of nonroutine instructions or cross-checking items).	4.0
	Work requires deep concentration (e.g., making swift mental calculations or memorizing items).	8.0
Any allowance for the lighting on the job site.	Continual glare on work area. Work requiring constant change of light. Less than 75 foot candle power on work surface for normal work. Less than 125 foot candle power on work surface for close work.	2.0
Any allowance for noise on the job site.	Constant, rather loud noises over 60 decibels (e.g., machine shops or	1.0

	motor test shops).	
	Average constant noises, level but with loud, sharp, intermittent, or staccato noise (e.g., nearby riveters or punch presses).	2.0
	0.00 to 0.20 minute cycles	4.0
	0.21 to 0.40 minute cycles	3.0
	0.41 to 0.80 minute cycles	2.0
	0.81 to 2.50 minute cycles	1.0
	2.51 minutes or more	0.0

Fatigue Allowance Considerations (cont)		
Personal allowance documentation should document:	Considerations	Typical Percentage Allowance
Any allowance for the use of safety devices or clothing.	No allowance should be made here unless it is necessary to remove the equipment occasionally for relief or if wearing the item causes fatigue.	
	Face shield	2.0
	Rubber boots	2.0
	Goggles or welding mask	3.0
	Tight, heavy protective clothing	4.0
	Filter mask	5.0
	Safety glasses	0.0

- **Delay Allowance.** A delay allowance covers unavoidable, predictable and unpredictable delays for such activities as replenishing materials, rejecting

nonstandard parts, making minor equipment repairs, and receiving instructions. The allowance:

- o Should consider delays inherent in the job, as well as the relationship between each job and adjacent jobs. The table below outlines some of the factors that should be considered.
- o Should not consider delays that can be prevented by the employee or for rework/repair of substandard parts.

Delay Allowance Considerations		
Personal allowance documentation should document:	Considerations	Typical Percentage Allowance
Basic Allowance	Isolated job. Little coordination with adjacent jobs.	1.0
	Fairly close coordination with adjacent jobs.	2.0
	Worker moves once each 5 minutes.	5.0
	Worker moves once each 30 minutes.	3.0
	Worker moves once each 60 minutes.	2.0
	Worker moves once each 2 hours.	0.0

Special Allowances. Any proposed special allowance must be supported by detailed engineering analysis. An appropriate study should be conducted in each shop or functional area to ascertain any requirement for a separate delay allowance. The analyst should assure that there is no duplication between cycle time elements and allowance elements and that the Special Allowance does not become a dumping ground for operation activity that is not an integral part of shop work load.

- Work elements such as cleaning chips from equipment, tool care, or tool replacement, though occurring irregularly, should be measured and the time required

- prorated directly to the machine operating portion of the work cycle rather than as an allowance.
- Certain other irregularly occurring elements having a direct relationship to the job such as obtaining parts and materials and periodic inspection should be added to the cycle time on a prorated basis or as a separate work element rather than added as an allowance.

When a special allowance is appropriate, the time required is first calculated in minutes and then converted to a percentage. The base for calculating and applying the allowance percentage is normally the sum of the leveled time and the PF&D allowance. Appropriate special allowances typically fall into two categories:

- Those that consider elements that occur on an unforeseeable basis:
 - Power failures of nonreportable duration.
 - Minor repairs to defective parts.
 - Waiting for a job assignment.
 - Obtaining job information from a supervisor, inspector, or production control specialist.
 - Unsuccessful hunt for parts or materials.
 - Machine breakdown of nonreportable duration.
- Those that consider elements that occur periodically (daily, weekly, hourly) such as:
 - Cleaning and lubricating equipment.
 - Work area clean-up.

Applying an Allowance to Leveled Time. Allowances are normally expressed as a percentage of standard time spent unproductively (e.g., a 15 percent PF&D Allowance indicates that 15 percent of the worker's standard time is spent unproductively). To apply an allowance, the analyst must determine how much the leveled time must be increased to allow for the unproductive time. This is accomplished by dividing the leveled time by the percentage of time spent productively.

$$T_s = \frac{T_L}{1.00 - A_{PF\&D}}$$

Where:

T_s = Standard time

T_L = Leveled time

$A_{PF\&D}$ = PF&D allowance in decimal form

For example: The leveled time for a particular task is 170 minutes, the PF&D Allowance is 15 percent, and there is no special allowance. The standard time would be calculated as:

$$\begin{aligned} T_s &= \frac{T_L}{1.00 - A_{PF\&D}} \\ &= \frac{170}{1.00 - .15} \\ &= \frac{170}{.85} \\ &= 200 \text{ minutes} \end{aligned}$$

Note: The leveled time is 85 percent of the standard time (85% of 200 is 170). The remaining 15 percent of the standard time (15% of 200 minutes is 30 minutes) is the allowance for personal, fatigue, and delay factors.

8.3 - Measuring And Projecting Operation Efficiency

Comparing Labor Standard with the Actual Time. Standards represent goals for efficient operation. Tasks are rarely completed in the allowed standard time. Work Measurement Systems commonly use realization or efficiency factors to evaluate how the actual time required to complete a task compares with the standard time for that task. Analysts can then use these measures to identify tasks that require special analysis to identify and correct inefficient operations.

Since estimators strive to estimate realistic contract costs, they use realization or efficiency factors with labor standards to estimate future labor hours required to complete the task.

Calculating a Realization Factor. A realization factor is generally a measure of overall performance (e.g., shop, product line, or plant). It will normally be calculated from historical data as:

$$F_R = \frac{T_A}{T_S \times R}$$

Where:

F_R = Realization factor

T_A = Actual time to perform the work

T_S = Standard hours for the task

R = Repetitions of the task included in the work

Don't be confused by the fact that some firms refer to this calculation as an efficiency factor.

For example: A task has a standard time of 1.5 hours. Actual time to perform the task 100 times is 300 hours. The realization factor would be calculated as follows:

$$\begin{aligned} F_R &= \frac{T_A}{T_S \times R} \\ &= \frac{300}{1.5 \times 100} \\ &= \frac{300}{150} \\ &= 2.00 \end{aligned}$$

In the above example, actual experience shows that the work takes twice as many hours as the standard time indicates.

Developing an Estimate Using a Realization Factor. The estimator can use the standard time and realization factor to develop a realistic labor-hour estimate.

For example. An estimate of the actual time to complete the task above for 50 units would be calculated as:

$$\begin{aligned} Y &= T_S \times R \times F_R \\ &= 1.5 \times 50 \times 2.00 \\ &= 150 \text{ labor hours} \end{aligned}$$

Where:

Y = Estimated hours

All other symbols are as defined above

Calculating an Efficiency Factor. An efficiency factor is calculated to demonstrate efficiency against the standard (e.g., a task with an efficiency factor of .60 is being performed at 60 percent efficiency). The factor is normally calculated:

$$F_E = \frac{T_S \times R}{T_A}$$

Where:

F_E = Efficiency factor

All other symbols are as defined above

For example. A task has a standard of 1.8 hours. Actual time to perform the task 100 times is 400 hours. The efficiency factor would be calculated as follows:

$$\begin{aligned} F_E &= \frac{T_S \times R}{T_A} \\ &= \frac{1.8 \times 100}{400} \\ &= \frac{180}{400} \\ &= .45 \text{ or } 45 \text{ percent efficiency} \end{aligned}$$

Developing an Estimate Using an Efficiency Factor. The estimator can use the standard time and efficiency factor to develop a realistic labor-hour estimate.

For example. An estimate of the time to complete the task above for 50 units would be calculated as:

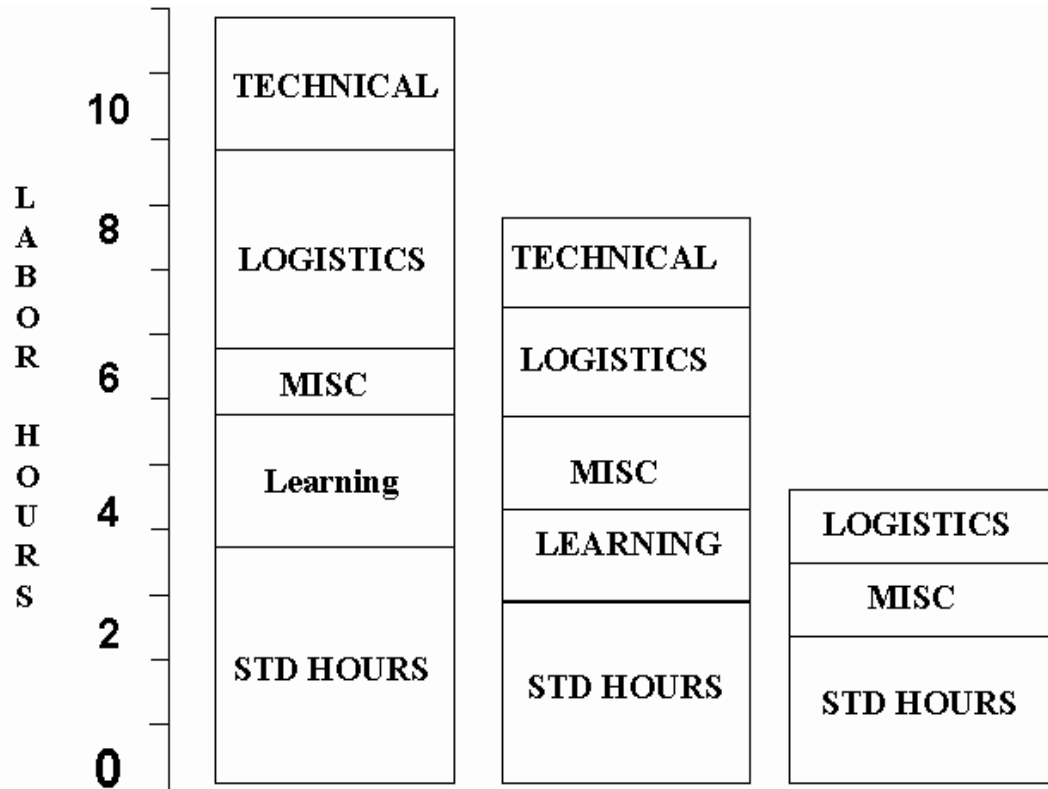
$$\begin{aligned} Y &= \frac{T_S \times R}{F_E} \\ &= \frac{1.8 \times 50}{.45} \\ &= 200 \text{ labor hours} \end{aligned}$$

Analyzing Realization and Efficiency Factors. Analysis of labor estimates developed using labor standards requires extensive knowledge and experience. Even skilled industrial engineers typically require special training in work measurement analysis. As a result, you should normally request technical support whenever an offeror estimates labor hours using labor standards.

For each standard, offerors should be required to provide information on internal analyses of the variance between the actual time required to complete the work and the standard time to determine the causes for the variance and identify ways of managing performance improvement.

You should expect offeror's to demonstrate continued improvement in realization and efficiency factors. The figure below depicts some of the reasons for that improvement.

- At Unit #1, total labor-hours include substantial inefficiencies related to technical, logistics, learning, and other factors.
- As production increases, there should be reductions in all areas of inefficiency. In most cases, there should also be an improvement in the labor standard itself, as better production methods are identified and implemented.
- By Unit #1000, the contractor should be operating efficiently, with only minor inefficiencies related to such factors as unavoidable parts shortages.



Typical Variances from Standard during a Production Program

However, improvement will not automatically follow this pattern. Effective analysis and management effort are required. Even when these are present, improvement may be hampered by factors such as repeated changes in design or production methods.

Still, the goal of both the contractor and the Government should be continuous improvement. Even when operations are being performed at or close to standard, the contractor should be searching for methods improvements that will reduce costs and improve overall efficiency.

Projecting Realization and Efficiency Factors. Be cautious of any estimate for continuous production that does not consider variance reduction following the improvement curve. Continuous improvement is one of the reasons for using labor standards, because standards provide detailed information on the areas that offer the greatest opportunity for improvement.

Improvement curves and moving averages are commonly used to project variation from labor standards. Either technique can be acceptable depending on the situation. Technical assistance can be very valuable in evaluating offeror forecasts.

- **Improvement Curves.** Using an improvement curve to track and project variance from a labor standard assumes that the variance is related to the number of units produced. As more units are produced, the variance is expected to decline following improvement curve theory.
- **Moving Averages.** Firm's often use moving averages to track and project variance from a labor standard when the variance is not expected to follow an improvement curve. This assumption is often valid when product production is not continuous or there are frequent changes in design or production methods.
 - While moving averages are an acceptable way to track and project variances, do not forget that a firm could be using a moving average to hide a downward trend in the data. That is particularly true in cases where the firm proposes a single moving average calculated over a large number of periods.
 - Government technical personnel can provide invaluable assistance in assuring that averages are not masking a trend in the data and that data from one or two periods are not unduly affecting the average.

8.4 Identifying Issues And Concerns

Questions to Consider in Analysis. As you perform cost analysis, consider the issues and concerns identified in this section, whenever you use work measurement.

- ***Is the offeror using available standards and realization or efficiency factors to estimate contract cost?***

If the offeror has an active Work Measurement System, the System provides vital insight into direct labor costs. Information on related time standards and variance analysis are cost or pricing data and must be provided by the

offeror whenever you require cost or pricing data. You should also consider requesting information on time standards and variance analysis, whenever you require an offeror to submit information other than cost or pricing data.

- ***Were standards developed using appropriate process analysis and accepted methods of standard development?***

Many firms refer to historical costs as standards. Using historical costs does not provide the methods analysis and engineering discipline normally associated with the use of engineered labor standards in estimating.

- ***Are realization or efficiency factors based on experience with the same or similar products and processes?***

In a cost proposal, either factor should consider experience with the same product or similar products and processes. A realization standard at one facility should not be used at another facility unless the conditions are the same. Do not compare realization factors for one facility with those for other facilities.

- ***Are standards and factors current?***

The data used to develop standards should be current and representative of current methods, facilities, and working conditions. Realization/efficiency factors should be based on the current standards. If you have questions or concerns, seek assistance from Government technical and audit representatives.

- ***What efforts are being taken to control variance from labor standards?***

Reasons for the differences between the standard hours and actual hours should be explained. Improvement curves are often used to estimate the reduction of variances from standard as production continues. Setting and achieving aggressive goals for improvement of realization or efficiency factors beyond historical improvement curve effects should be a prime factor in reviewing contractor performance.

- ***How are rework and repair considered in the estimate?***

Rework and repair occur when a part or assembly is rejected in an inspection or test and sent back for correction of the deficiency. In addition, some completed parts and assemblies must be reworked to incorporate design changes. The cost of rework should not be included in the labor standard, related allowances, or the realization factor. Instead, time spent on rework should be accounted for separately. However, labor standards can be used in estimating the labor effort required for rework. Historical rework costs should be carefully screened to eliminate rework costs associated with one-time problems or changes.

- ***Is the method used for realization or efficiency factor forecasting appropriate?***

Use of improvement curves is appropriate in continuous production situations that should foster variance reduction. Use of moving averages is appropriate in situations where sporadic production or other factors hamper efforts to reduce any variance from standard.