How to Design and Conduct a Computer-Integrated Time Study with Active Element Performance Rating (CITS APR)

DEFINITION OF TIME STUDY

A time study is an analytical procedure used to establish the preferred method of accomplishing a task and to establish the "fair day's work" time necessary for an operator to complete that task.

In an engineered time study, the work cycle is broken down into work elements (sequential, recognizable tasks). These elements are timed using an analog or electronic watch or computerized methods (as in the case of CITS APR). The work is pace (or performance) rated so the times reflect the performance of a normal (i.e., normal motion speed, effort) operator. The result of a time study is an engineered standard time that considers the performance (pace) rate of the operator during the study; that proper training has been given the operator; and that time has been provided to accommodate personal needs (P), rest to overcome fatigue (F), and the unavoidable delays (D), [sometimes termed P, F, & D], inherent to the work.

C. R. Lindenmeyer, 1997
(revised, July, 2001)

THEORY OF TIME STUDY

The basic theory behind time study is that if a statistically based sample of elemental times is obtained that the resulting mean time for the work element represents a time to accomplish the task within a certain percent accuracy of the true mean time for the task. The theory also infers that the addition of the normalized elemental times represents the correct normal time for the work cycle.

TIME STUDY PROCEDURE – STEP-BY-STEP

1. Obtain and record information about the operation and operator being studied. Use pre-printed forms if available. Make a workplace sketch (or CAD drawing). Use a video record if that is available.

2. Make sure the operation is ready to be studied. Make "easy" methods improvements where possible.

3. Divide the operation into elements and record a complete elemental description of the cycle. Record the ending "Therblig" (basic motion) for each element.

4. Observe and record the time taken by the operator.

5. Determine the number of cycles to be timed (repeat steps #4 and #5 as necessary). With CITS APR this repetition can sometimes be avoided using the real time accuracy or number of observations feedback.

6. Rate the operator's performance (pace, speed, effort). Pace (performance) rating is a learned skill (many industrial engineers call it an art).

7. Download the CITSWCE data file to the desktop PC for further data analysis.

8. Enter additional study information on CITS APR's Study Information screen.

9. Enter or modify the performance rating(s).

10. Enter the frequencies for each element whose occurrence is less than once per work cycle.

11. Enter the allowances (P, F, & D) for each element or the work cycle overall.

12. If necessary, analyze data for outliers (abnormal times) and exclude these times if justified.

13. Determine (calculate) the time standard for the operation. CITS APR does this for you automatically.

14. Follow-up to ensure the work standard is accurate (i.e., it represents a reasonable work expectancy) and the preferred method is being followed. Make and document additional methods improvements.

"You cannot manage what you do not measure." CRL, 1994

OBTAIN AND RECORD INFORMATION ABOUT THE OPERATION AND OPERATOR BEING STUDIED

Many I.E.s will want to make detailed workstation layout drawings and or take Polaroid or other type photos of the operation area from many different vantage points. Some brands of Handheld PCs (H/PCs), Sharp in particular, now have camera accessories that are built-in and electronic images may be captured for downloading to the Industrial Engineer's desktop PC for inclusion in the operation’s standard work methods file.

In CITS APR, the data are collected on a Handheld PC using Windows CE operating system. The program that resides on the H/PC is called CITSWCE. When first invoked, CITSWCE shows the Study Information screen. The CITSWCE Study Information screen is shown in Figure 1.

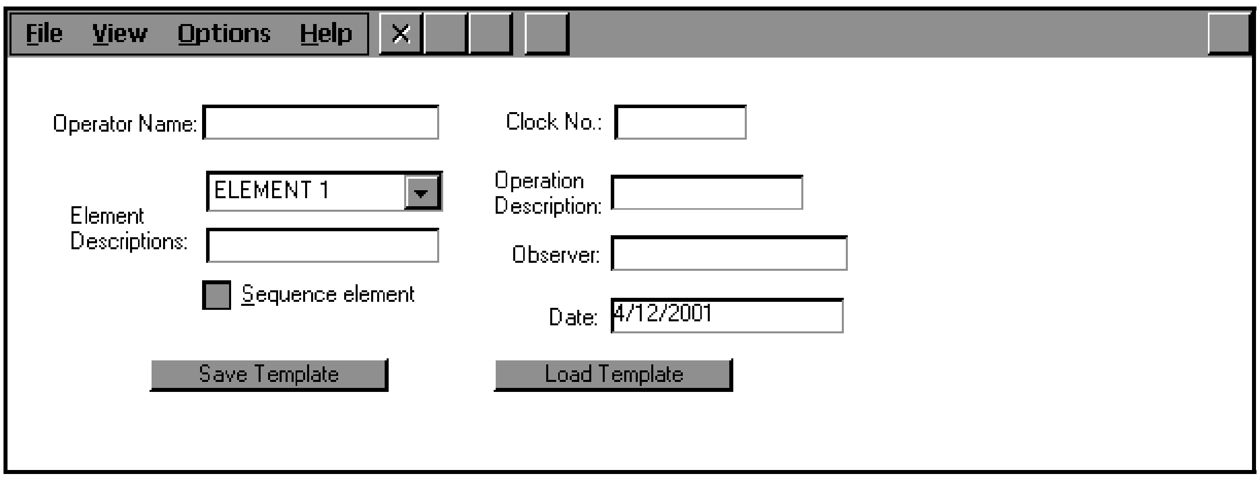

Figure 1. CITSWCE Study Information Screen

The Study Information screen allows the analyst to enter the Operator Name and Clock Number, Operation Description, Observer, and the Date. The date defaults to the date in the H/PC. The analyst can also describe up to 20 elements for the study and set-up automatic sequencing for data collection on highly repetitive and short elemental times (See the CITS APR User Documentation for more information). Once this information has been entered, the analyst can save this information in a template for future use on the same or similarly documented operations. If the template has already been designed, it can be loaded for re-use.

To give the analyst mnemonic (memory) assistance in identifying the element to be timed, the first four (4) characters in each element’s description can be made to appear in each of the data collection screen’s element timing “buttons.” This option is also invoked from any of the CITSWCE screens by clicking on “View” and selecting/checking “Show Label.” Please refer to the CITS APR User Documentation for more information on the use of this option.

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Professor Emeritus of Industrial Engineering

MAKE SURE THE OPERATION IS READY TO BE STUDIED

Here are a few questions you should ask (and get answers to) before you start a time study:

- ✓ Can the speed or feed of the machine/process be increased without affecting optimum tool life or without adversely affecting the quality of the product?
- ✓ Can changes in tooling be made to reduce the cycle time?
- ✓ Can materials be moved closer to the work area to reduce non-value adding handling time?
- ✓ Is the equipment operating correctly?
- ✓ Is a quality product being produced?
- ✓ Is the operation being performed safely?
- ✓ Are effective ergonomic practices being followed and is the operator's comfort being considered?
- ✓ Is the operator using the preferred method?
- ✓ Are there "easy" methods improvements that can be made right now?
- ✓ Is the operator attempting to mislead you (padding the time, employing extra and unnecessary motions, slowing down the motion pattern)?

If there are discrepancies in terms of use of the preferred method, or improper tooling, or any other deviation from standard operating procedure (SOP), these should be noted in the study documentation. If there are methods improvements to be made in the future, these also should be noted. A narrated videotape of the operation with your SOP commentary and possible methods improvement notes may be an excellent way to not only document the operation but to prepare the way for continuous improvement.

Once you are satisfied that the operation is running properly, you are ready to start the CITS APR study.

DIVIDE THE OPERATION INTO ELEMENTS AND RECORD A COMPLETE DESCRIPTION OF THE WORK METHOD

Briefly describe each element (sequential operation task) of the work cycle on the CITSWCE Study Information screen. See Figure 2 for a graphical example of an elemental breakdown on a simple operation . Some "rules" (or general advice) on dividing a work cycle into elements are as follows:

- ✓ Elements should be short in duration but not so short as to make them difficult to time. However, quite short elements can be timed using CITS APR's "Allow Sequencing" feature. See the user documentation for more information on this CITS APR option. To invoke "Allow Sequencing" click on "View" and then check (✓) "Allow Sequencing." Using this option the analyst can capture elemental times on repetitive work by simply using the <ENTER> key.

- ✓ Take advantage of audible sounds to aid you in capturing the time at the end of a work element. Examples include where a sound occurs when the operator drops a part in a tote pan or a sound when a machine cycle ends.

- ✓ Manually controlled handling time should be separated from machine or process time.

- ✓ Constant time elements should be separated from variable time elements. Variability can manifest itself within an element in a work cycle or between similar elements within group technology-based families (departments) of work (see next point).

- ✓ Always consider the use of resulting elemental time data on future work or on other operations in the department. Statistical multiple linear regression analysis may be used to develop algebraic time formulas/models for group technology-based families (often, departments) of work. Appropriate elemental breakdown is essential to the development of these time formulas. Where applicable, use of algebraic time formulas can vastly reduce the amount of time study necessary in a department.

◄── 0.810 minutes - Total Cycle Time ──►		
Element #1 Load Part and Start Machine	**Element #2** Machine Part	**Element #3** Remove Part from Machine, Check for Quality, and Dispose
(0.180 minutes - manual time)	(0.360 minutes - machine controlled time)	(0.270 minutes - manual time)

Figure 2. A Graphical Example of Elemental Breakdown for a Simple Operation

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OBSERVE, RECORD, AND RATE THE TIME TAKEN BY THE OPERATOR AND CHECK TO MAKE SURE YOU HAVE TAKEN ENOUGH OBSERVATIONS

Collecting time data is a relatively simple task using the CITSWCE program on the H/PC. The Data Collection screen for CITSWCE is shown in Figure 3.

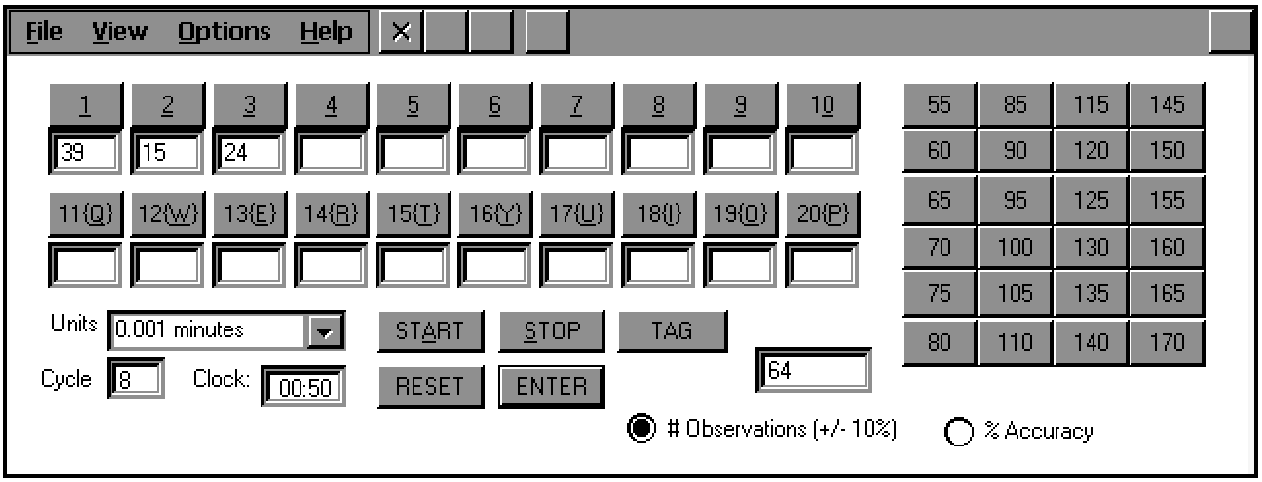

Figure 3. CITSWCE Data Collection Screen

The procedure for starting and conducting a CITS APR time study is as follows:

1. Select the time units you wish to use for the study. Click on the down arrow in the "Units" section of the screen and select from 0.001 minute (the default timing unit), 0.01 minute, 0.0001 hour, or 0.00001 hour (the MTM-1™ timing unit termed a TMU). On short cycle operations, 0.001 minute or 0.00001 hour should be used. On long cycle operations where a work element's time can reach 10 or 15 minutes or more, the other time units, i.e., 0.01 minute or 0.0001 hour should be used.

2. Make sure you have selected the desired options (either or both of "Allow Sequencing" and/or "Show Labels." To select one or both of these features click on "Options" and check the appropriate option you wish to employ.

3. When ready to start your study, click on "START."

4. If you wish to use the Active Element Performance Rating (APR) feature, before capturing the time for the first element you wish to time, click on the correct pace/performance rating percentage for that element (you can choose from between a 55% and 170% pace rating). The default is 100%. You do <u>not</u> have to use this feature if you do not wish to do so. Do this for each element before you capture its time. The pace/performance rating for an element will remain as you have rated it until you change it or until the end of the study.

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5. At the end of each element's time, click on the corresponding element button. Before you collect the next element's time, select the appropriate rating factor (%) and then capture the element's time.

6. If a foreign element or anything out of the ordinary occurs or you just wish to make a note during the study, you can use the "Tagging" feature. Let's say the operator drops a part during Element 1 of an operation. Before you capture the end time for Element 1, click on the box "Tag" and a window will pop up where you can enter a single alpha character for the tag and even type in a brief description of the interruption, e.g., "drop part." Once you click "OK" in the Tag Window, you will return to the Data Collection screen so you can capture the end time for Element 1.

7. Check your accuracy as you go along during the study. After five cycles for a particular element, you can check to see if you have taken sufficient observations. You have a choice of two different measures: (1) the number of observations necessary for 95.4% confidence limits and ±10% accuracy, or (2) the actual ±% accuracy, given the number of observations you have actually taken to that point in time. See Figure 3 to see the two radial buttons used to change from one form of accuracy feedback to the other. It is important to note that this feature is of limited use if the analyst obtains a "wild" or a severe outlier data point. The accuracy figures "blow up" to a point where they are not very useful to the analyst. If, however, the analyst is obtaining normally distributed readings without great variability, the feature is quite useful in that it provides the analyst with knowledge that enough readings may have been taken and the study may be concluded.

8. When you are finished with your study, simply click on "Stop." If you want to pause the study, let the H/PC run after you have captured the last element's time and after the pause (e.g., lunch, break, etc.) click on a dummy element (e.g., element 20, if that is not used in the work cycle). This time may easily be excluded from the final analysis of the data.

Frank and Lillian Gilbreth – Two Pioneer Industrial Engineers

DOWNLOAD THE CITSWCE DATA FILE FOR FURTHER DATA ANALYSIS

The procedure for downloading the time study data file from the H/PC to the desktop PC is straightforward and simple:

1. Hook the H/PC up to the serial port of your desktop PC.

2. Make sure "ActiveSync" is running.

3. Drag and drop the data file from the H/PC to the desktop window of your desktop PC.

4. Invoke CITS APR on the desktop PC and load the data file

ENTER ADDITIONAL STUDY INFORMATION

The study information that you entered on the handheld PC can now be expanded with entries on the first CITS APR desktop PC screen. Much more information including lot identification and size, set-up time, tooling specifications, etc. can be entered at this time. The Study Information screen is shown in Figure 4.

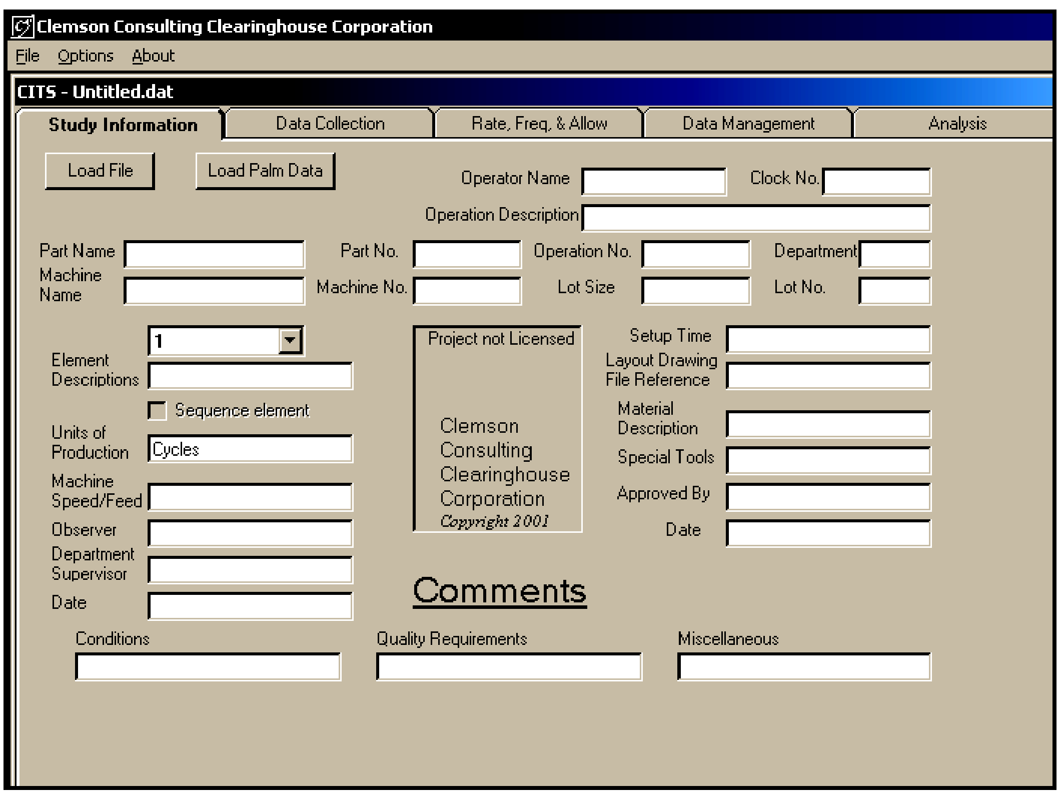

Figure 4. Study Information Screen

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ENTER OR MODIFY THE PERFORMANCE RATING(S)

Now, click on the "Rate, Freq. & Allow" tab. Here, you can modify (or enter for the first time) the performance ratings for each element of the job, or the work cycle overall. If you have used the Active Element Performance Rating (APR) feature in CITSWCE, you will see the pro-rata average performance ratings for each element you rated. If you did not use the APR feature and you now wish to apply ratings to each element or the overall work cycle you may do so. If you did use the APR feature you can modify (change) the rating factors. In either case (rate for the first time or modify/change existing rating factors) you must overrule the APRs. If you did not rate the operation the default APRs will all be 100%. The Rate, Freq. & Allow form is shown in Figure 5 and the top section is used for the Performance Factor(s) Entry.

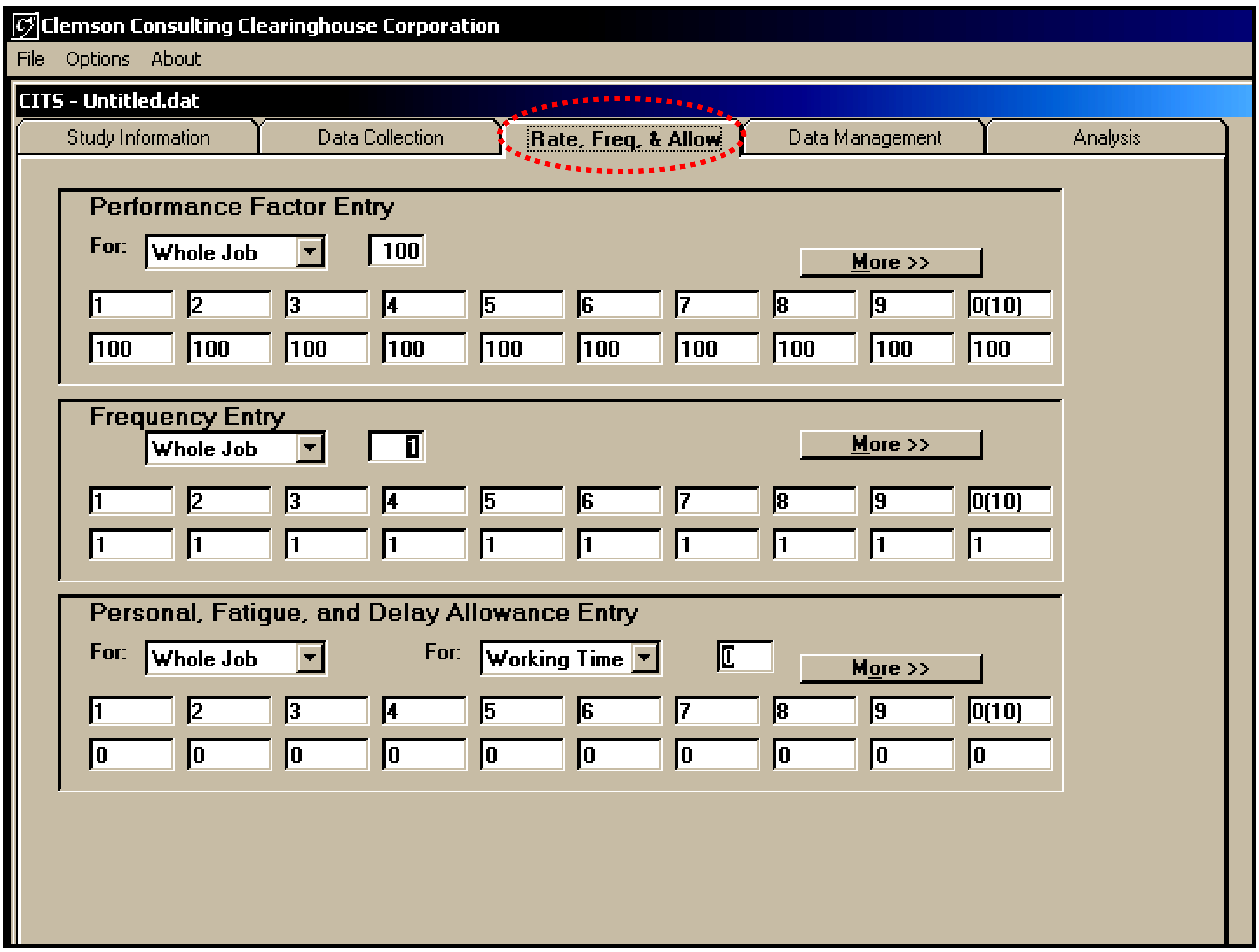

Figure 5. Rate, Freq. & Allow Screen

ENTER THE FREQUENCIES FOR EACH ELEMENT

If you timed any elements that occurred less than once per work cycle, you can enter the frequencies for these elements at this time. The default frequency is one (1) for one occurrence each cycle. Non-cyclic elements (e.g., stock-up of parts, quality control checks, tool adjustment or sharpening, etc.) that occur less than once time per cycle should have their frequencies entered. An example might be a quality check that occurs once each ten normal work cycles. In the case of this quality check that occurs once every ten cycles, the frequency entered would be "**.1**" (do not include quotes). See the middle section of Figure 5 for the Frequency Entry portion of this form.

ENTER THE ALLOWANCES FOR EACH ELEMENT OR THE WORK CYCLE OVERALL

The P, F, and D (Personal, Fatigue, and Delay) allowances may be entered at this time. Please refer to the bottom section of Figure 5. The allowances may be applied to each element separately (such as in the case of having a lesser allowance for machine controlled elements) or to the cycle overall. After this decision is made, the base of the allowance must be selected, i.e., the working minutes of the shift or the entire minutes of the shift. The allowance percentages are entered as percentages, e.g., if the allowance is 72 minutes out of an entire 480-minute shift, the allowance is 15%, and 15 is entered as the allowance and the base for the allowance is the entire shift. If the analyst wanted to base the allowance on the working minutes of the shift (480 – 72 = 408) then the allowance percentage is 72/480 x 100 = 17.6% and the base for the percentage would be the working minutes. In either case the standard time for the job would be the same. For more information on calculating the standard, please refer to Appendix A, "Calculating the Standard Time."

ANALYZE THE DATA FOR OUTLIERS (ABNORMAL TIMES)

Once you are finished with the screen described above, you may analyze your data to detect outliers (statistically abnormal times) by bar-charting the elemental times in the sequence in which they were taken or view a frequency distribution histogram (bar chart) of the elemental times to see the distribution shape (often, but certainly not always, a normal "bell" shaped curve). The sequence histogram is normally of great interest. The frequency distribution histogram also is useful, but you normally need 20 observations or more for this feature of data management to be an effective statistical tool.

Data points may be excluded (only with professionally based justification, of course) and the effect of this data exclusion, which will usually reduce the variability of the data, will be to improve the accuracy of the sample's prediction of the mean elemental time. In the data management screen row titled "OBS" the number of observations needed for 2 sigma confidence limits and ±10% Accuracy is shown. In the row titled "ACC," the actual ±% accuracy is shown, given the number of observations taken (or remaining after data removal). See Figure 6 for an example of the Data Management CITS APR screen showing a Sequence Histogram for Element #1 in the time study.

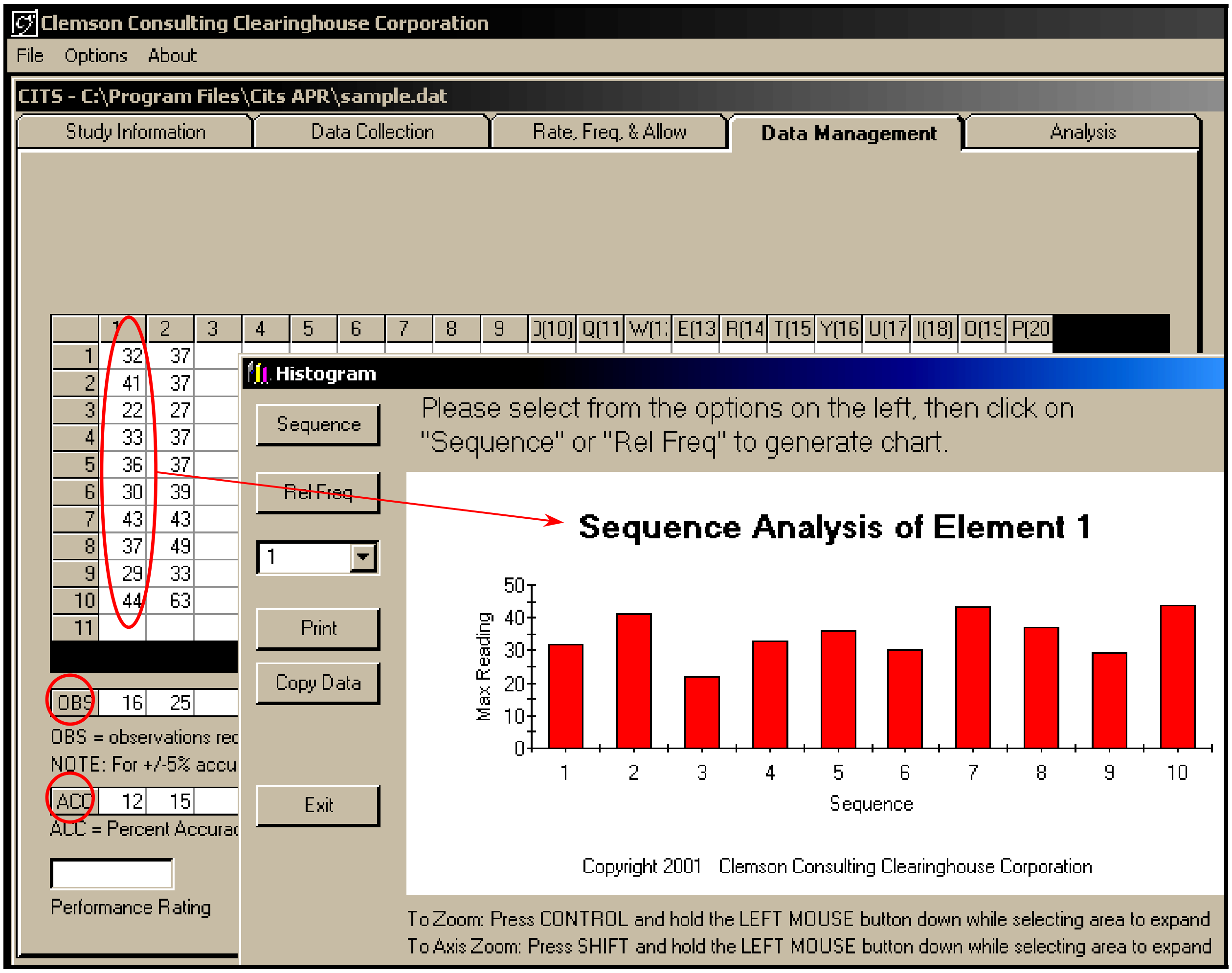

Figure 6. Data Management Screen

CALCULATE THE STANDARD TIME FOR THE OPERATION

Once you have entered your performance (pace) rating factors, the elemental frequencies (if the occurrence is less than once per cycle), and the P, F, and D allowance(s), you may, if necessary, go to the Data Management screen (as described in the previous monograph section and illustrated in Figure 6) to look at and modify (i.e., perhaps eliminate) any data point, element by element, using the Sequence or Frequency Histogram charting feature in CITS APR.

Once you are satisfied with your data, click on the "Analysis" tab at the top of the CITS screen and you are essentially done! Note that either the mean or the median may be used. See Figure 7 for an example of a final analysis.

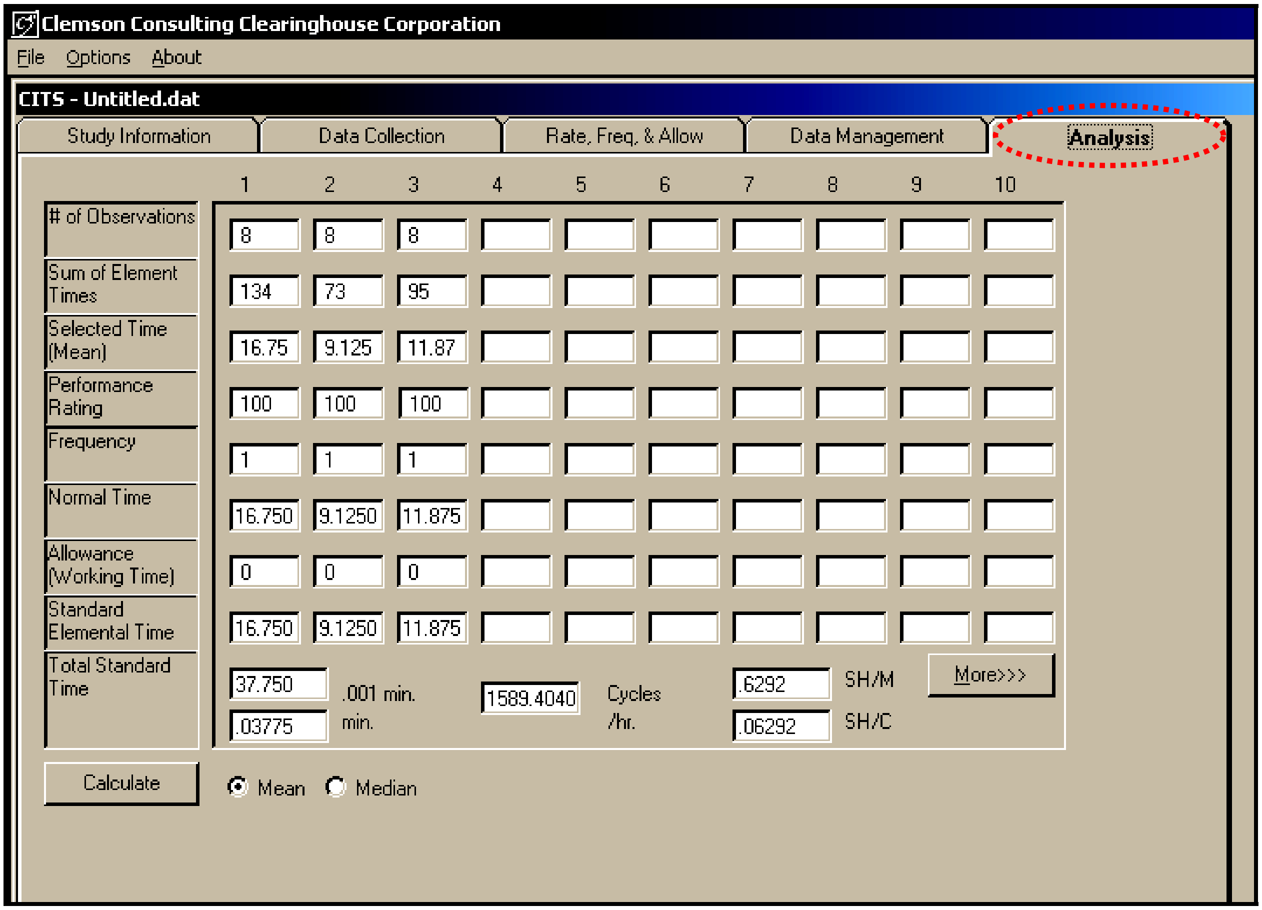

Figure 7. Final Analysis Screen

Follow-up

Now that you have finished the study you can print out the results through CITS APR or export all or some of the reports to Excel. However, you really are not done. You need to follow-up to make sure the resulting work standard is accurate and represents a reasonable or "fair days" work expectancy. You should also be aware that methods "slippage" occurs and be watchful against this happening. Having good methods documentation and proper training will help here.

Make sure you document your ideas for future methods improvements and practice "continuous improvement." The people doing the job will be your best ally in your methods improvement efforts.

Appendix A -- CALCULATING THE STANDARD TIME

1. Get Observed Elemental Times (OET). If a snap-back study, the OET will be read directly. If a continuous study, subtract consecutive watch readings to arrive at the OETs. Do this for each element.

2. For the first element add up the OETs and divide by the number of observations (n) for that element. This will be the Average Observed Elemental Time (AOET).

   $$AOET = (\Sigma\, OET)/n$$

   Do this for each element.

3. For the first element, calculate the Normal Elemental Time (NET). This is done by multiplying the AOET by its associated performance rating factor (RATING) expressed as a decimal. The decimal equivalent of a percentage is the percentage divided by 100.

   $$NET = AOET \times (RATING)$$

   Do this for each element.

4. If all the elements will have the same personal, fatigue (rest to overcome), and delay (P, F, & D) allowance applied to them, sum the NETs to get the total normal time (TNT) for the task. If the elements have different P, F, &D allowances applied to them the next steps (#5 and #6) will have to be done for each element individually and you will then sum the Standard Elemental Times.

   $$TNT = \Sigma\, NET$$

5. Determine the allowance factor for personal time, fatigue, and delays (P, F, & D) and express it as a decimal (Allow). There are two ways of basing this percentage, which are:

   a. Based on the whole 480-minute day.

   Example: 72 minutes of 480 minute (whole day) are for P, F, & D. Therefore the decimal allowance on this basis would be:

   72/480 = 0.15 (or 15% expressed as a percentage).

b. *Based on the productive (normal, working) minutes of the day.*

Example: 72 minutes of 480 minute (whole day) are for P, F, & D. Therefore the decimal allowance on the working minutes (480 – 72 = 408) would be:

72/(480 – 72) = 72/408 = 0.176 (17.6%)

6. Calculate the standard time (ST) by applying the allowance factor. Again, there are two ways of applying this factor, depending upon the base to which the allowance percentage relates. The two procedures for calculating the ST are:

a. *Based on the entire 480-minute day.*

ST = TNT/ (1 – Allow)

Example: 72 minutes of the whole 480-minute day.

72/480 = 0.15 (P, F, & D allowance percentage expressed as a decimal)

ST = TNT/ (1 – 0.15) = TNT/0.85 *(which is equal to [TNT x 1.176])*

b. *Based on just the productive (normal, working) minutes of the day.*

ST – TNT (1 + Allow)

Example: 72 minutes of whole 480-minute day.

72/(480 – 72) = 72/408 = 0.176 (P, F, & D allowance percentage expressed as a decimal)

ST = TNT (1+ 0.176) *(which is equal to [TNT/0.85])*

7. If desirable, convert minutes/cycle to standard hours per 100 cycles (SH/C) as follows:

$$SH/C = \frac{ST\ min.}{cycle} \times \frac{100\ cycles}{C} \times \frac{1\ hour}{60\ min.}$$

Other unit conversions may be appropriate, such as standard hours per 1000 cycles (SH/M), standard hours per piece, etc.

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AN EXAMPLE OF STANDARD TIME CALCULATION (CONTINUOUS STOPWATCH METHOD SHOWN HERE)

(All times are in 1/100ths of a minute, e.g., 43 = 0.43 minute)

Your subtracted sequential times go here, etc.

			ELEMENT		
			#1	**#2**	**#3**
CYCLE	**1**	**T**	43-0=43	63 – 43 = 20	etc.
		R	43	63	73
	2	**T**			
		R	113	29*	41
	3	**T**			
		R	86	210	20**
	4	**T**			
		R	65	86	95
	5	**T**	327−295=32		59-48=11
		R	327	***48	59
			95%	120%	100%
	P, F, & D Allowance = 15% of the Normal (Working, or Productive) Time.				

* this number is really **129** but the 1 is dropped for ease in data recording.
** this number is really **220** but the 2 is dropped for ease in data recording.
*** this number is really **348** but the 3 is dropped for ease in data recording.

CALCULATION STEPS

1. Calculate the Average Observed Elemental Times (AOET)

AOET #1 = _________
AOET #2 = _________
AOET #3 = _________

2. Calculate the Normal Elemental Times (NET)

NET #1 = _________
NET #2 = _________
NET #3 = _________

3. Total Normal Time (TNT) TNT = _________

4. Standard Time (ST) ST = _________

[If you calculated the Standard Time correctly you should have an answer of 0.849 min.]

Now, isn't it amazing that CITS APR does all this for you automatically?

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Notes: