How to Design and Conduct a Computer-Aided Work Sampling with Microsoft Excel (CAWS/E) Study

INTRODUCTION TO WORK SAMPLING

A Work Sampling Definition. "Work sampling is used to measure work activity proportions using random sampling. Usually, a large number of instantaneous observations are made at random times of one or more workers and/or equipment items over a representative period of time. When the study is complete, the ratio of the number of observations in a particular work activity to the total number of observations in the study yields an estimate of the proportion of total time spent in that activity. In Computer-Aided Work Sampling, each observation is "tagged" with its week, day, shift, hour, supervisor (or department), group under the supervisor (or department), and specific operator observed. The resulting database permits highly detailed reports and associated graphics. These charts and graphs illustrate comparative and trend information and present improvement opportunities about the organizational unit being studied."

Carl R. Lindenmeyer, 1996
(revised, June, 2001)

The Theory of Work Sampling. The basic theory behind work sampling is that the proportions of observations recording the subject of a study as idle, working, or in any other activity reflects, with a certain accuracy, the proportion of time actually spent by that subject in that activity. If the observations are randomly distributed over a sufficiently long and representative time, the theory will hold true, no matter what the nature of the activity is. Work sampling may be like a series of instantaneous and random time Polaroid™ photographs with the advantage of the analyst being able to interpret and categorize the activities observed.

Inference Through Sampling. Work sampling, as these terms imply, uses the time-tested principle of drawing inferences based upon a random sample from a population. In this case, the population is the total time distribution of all activities under study within the window of the total time the study is conducted. In work sampling, inferences are drawn as to the proportion of time the study subject(s) are engaged in various productive tasks, indirect productive work, non-value adding time (or non-productive work), out-of-area duties, and rest and personal time. Work sampling may have distinct advantages over continuous observation (time study), subjective hunches or "guesswork," and the often-biased employee kept time log. The industrial use of making inferences using sampling is commonplace. Statistical sampling is widely used in industrial quality control and in direct time study.

THE WORK SAMPLING PROCEDURE – STEP-BY-STEP

1. Pick an area to study and determine and write down the objectives (a mission statement) for your study.

2. Define the population to be studied (can be personnel and/or equipment).

3. Only if the data are to be used for establishing *work standards*, select the measures of output that reflect the productive work of the subjects of the work sampling study (e.g., pieces or units).

4. Determine the period of time over which the sampling will be done. Ensure the period is representative and reflects the organization unit's normal operating cycle. Normally, work sampling studies range from one week to six weeks or more in overall duration.

5. Select and train the people who will conduct the sampling, who may include:

   - Industrial or manufacturing engineers, other staff people

   - Supervisors

   - Non-related personnel to the subjects being studied, e.g., production workers studying warehouse workers.

   - Out-source (consultant provides, temporary help, etc.)

   Make sure you cover important issues in the training (avoiding bias, making observations instantaneously, providing consistency, and being trip start punctual)

6. Formulate the activity categories (both general and sub-) for the sampling. These categories of work should be designed for ease of observation and be consistent with the objectives (mission) of the study.

7. Determine the number of observations needed for the study accuracy you desire. Practical considerations may also significantly influence this decision. Use formulas, tables, or the computer (e.g., CAWS Mod I).

8. Develop the necessary forms (custom template spreadsheets) and data collection procedures (observation points, routes, etc).

9. Conduct a preliminary study over a ½-day up to a 3-day period. Make sure your activity categories are complete and correct.

10. Make your rounds (trips) and observe and record the sampling.

11. Analyze the data collected, including all statistical calculations. The CAWS/E programs and the computer will be especially helpful here.

12. Graphically portray all trend and comparison data for ease in interpreting the study results. Use CAWS/E's Raw Data output, and Microsoft Excel's™ Pivot Table and Chart Wizard. See Figure 1 for an example of a graphic output of a CAWS/E work sampling study.

13. Prepare the final report for management, including conclusions and cost saving recommendations.

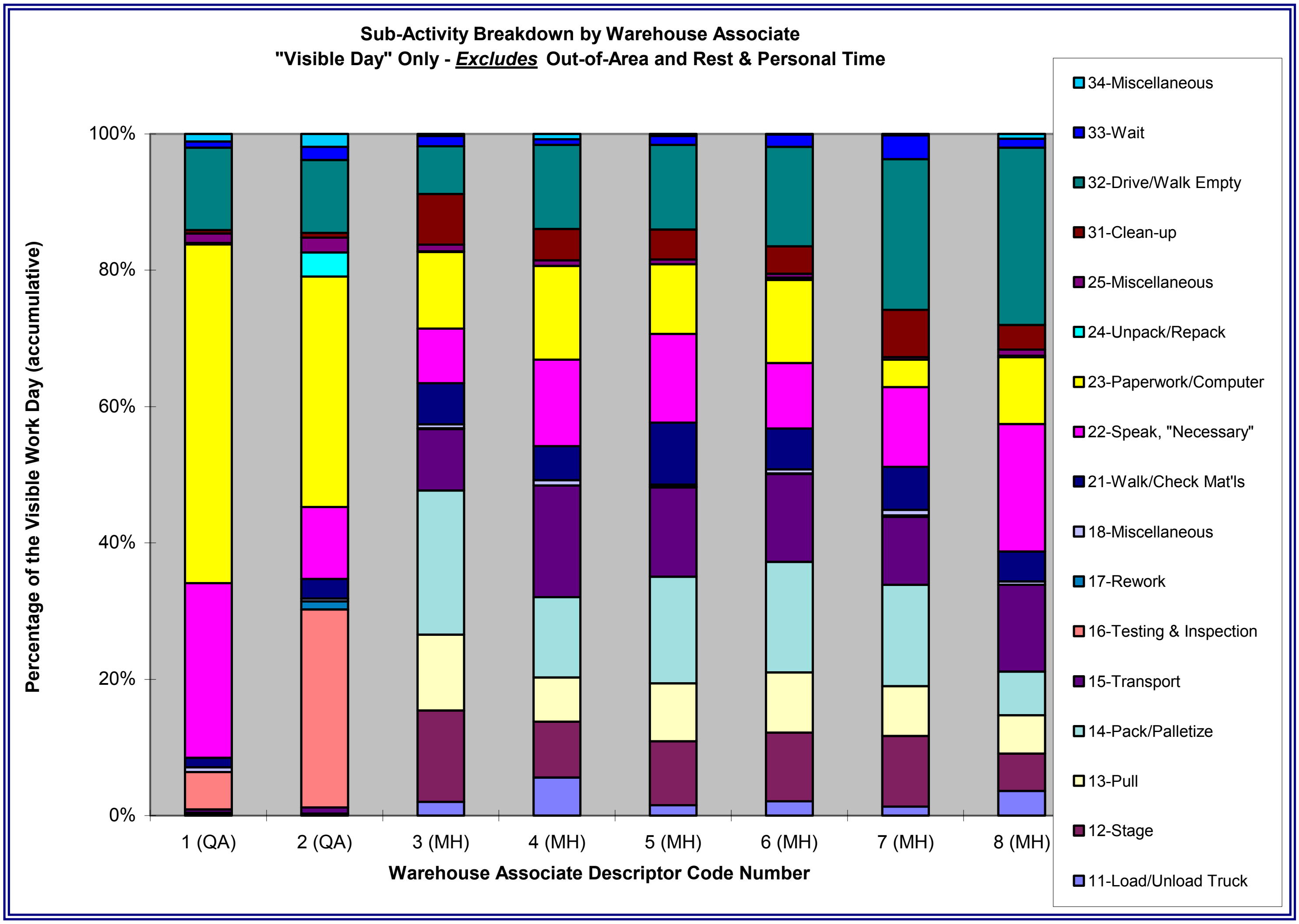


Figure 1. Example of Graphic Output of Results from a Warehouse CAWS/E Study.

PICK AN AREA TO STUDY

The first thing that should enter your mind when selecting an area to study is, will we get a "bang for our buck?" Covering too few subjects (people and/or equipment items) or trying to cover too large an area (square footage) will often result in your study not obtaining the informational or economic results desired. Just one of the many measures to employ in determining the scope of the study is to ask yourself, "How much time will it take the work sampling analyst to make an observation of one worker (or equipment item)?"

Now that we have many work sampling studies "under our belt" we have come to some general rules of thumb that will help an Industrial Engineering Department design a fruitful work sampling study. These work sampling study design "rules of thumb" are as follows:

- Try not to have fewer than five (5) subjects in the study (although we have done a study with 4 clerks in it).
- The time to make one observation on one of these subjects should not take more than 2 or 3 minutes.
- Try to pick areas to study that involve poor performance, worker complaints, lost production, late deliveries, and, in general, significant waste (MUDA).

As an example of what we are talking about, a large tire manufacturer wanted to study maintenance and repair in one of their facilities. In the rubber compound manufacturing facility there were 8 workers spread out over 250,000 square feet. In the company's main manufacturing facility they had a central maintenance department with 63 workers in an area of about 85,000 square feet. Although there were many other factors in the selection of the area to study (such as the need to compare different supervisors and compare different trade groups such as carpenters, mechanics, and electricians), the fact that so many workers could be studied with an analyst's trip taking a reasonable amount of time (about 50 minutes) that the 63 workers in their central maintenance department were chosen for the study.

Rule #1: Pick an area to study where you will get significant results for your study investment.

DETERMINE THE STUDY MISSION AND RESULTS REQUIRED

What is it that you want to learn from the study? Is it simply the percent of idle or waiting time? Do you want to know this proportion of time for all workers over all days of the study? Or, do you want to determine proportions of time for many different activities and want to have these numbers for different work groups for comparison purposes? Or, perhaps you want to see how the operators spent their time by day of the week – or by shift – or by hour of the shift?

It will be important for you to determine the answers to these questions before you conduct the study. You will need to take your intended study results and associated accuracies into account when designing the study.

You should determine a "worst case scenario" in terms of how many observations you will be taking to measure what you want "the numbers" on. For example, if you will be observing 25 workers each trip, but only two (2) workers are in a group you wish accurate numbers on, you will be collecting only two (2) observations per trip, not 25. Said another way, if you take 5000 observations in a work sampling study, but you want good accuracy on a sort report by day of the week you will be dealing with only 1000 observations for each day of the week.

Let me explain the importance of this by mentioning what an indirect labor industrial engineer told us at a Computer-Aided Work Sampling seminar/ workshop. This seminar was given by this professor at one of the world's largest automobile manufacturers. When I asked him how he determined the number of observations he was going to take in a work sampling study he said, "We estimate the percentage of time for the work activity we are interested in measuring. For example, in the last study we did, we determined that the smallest proportion of time we had interest in was 20% (it happened to be an idle or waiting time activity). We also determined that the relative accuracy desired was ±10% for an absolute accuracy of ±2%. We looked up the number of observations required for that study design and it was 1600 observations. Since we were going to observe 16 workers each trip we decided to take 100 trips. We determined our random trip times for these 100 trips over the duration of the study, which was 10 days. We took 10 random trips per day over the two weeks of the study. We reported to management that our accuracy on a 20% work activity was going to be ±2% absolute or ±10% relative."

I then asked the engineer what results were reported to management, that is, did he report just the overall proportions of time for the 20% time activity for all workers over the entire study – or did he report comparative data such as how the workers spent their time by day of the week – or hour of the shift, or by supervised work group. I also asked if the final report reported proportions of time less than 20%. He said (with a laugh) "all of the above." I then gave a (rather stern) lecture on statistical accuracy given the fact he reported proportions of time by day of the week. The fact was that he had taken only 1/5th of the total observations (on average) for each of the workdays in a week – or about 320 observations for Mondays, 320 observations for Tuesdays, etc. We calculated the

20% work activity's relative and absolute accuracies given the fact that only 320 observations were taken for each day of the week. Instead of ±10% relative and ±2% absolute accuracies, these turned out to be ±22.4% relative and ±4.5% absolute! Adding insult to injury, the engineer stated that he had reported proportions of time for work activities equal to or less than 5% without their corresponding accuracies. See Figure 2 for the accuracy analysis on a 20% work activity where the desired absolute accuracy is ±2%.

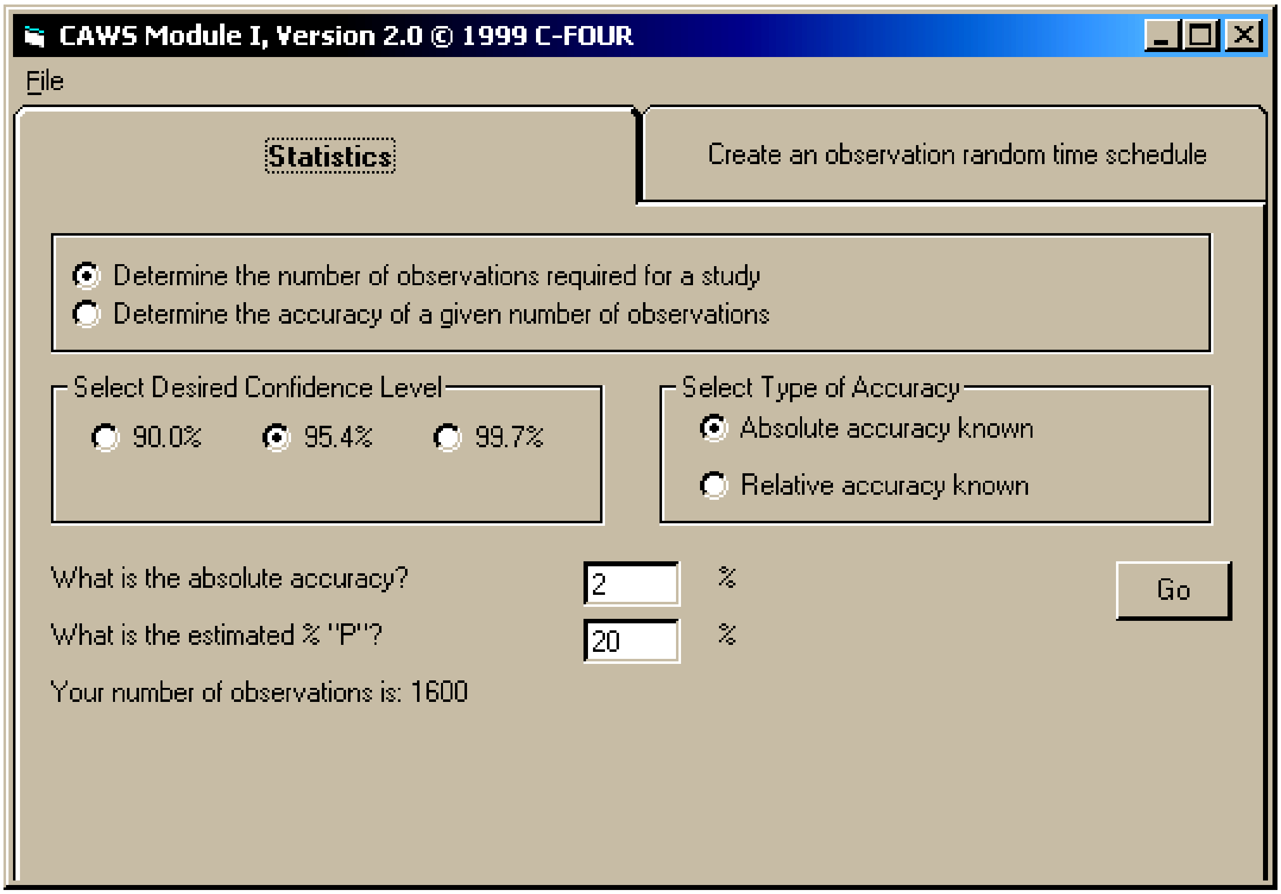


Figure 2. Example of a CAWS Mod I Work Sampling Study Design Analysis

The bottom line is this. Determine how fine you want to "slice and dice" your data and take the appropriate number of observations to obtain the accuracies you wish to report. In the above example, the engineer at one of the world's largest automobile manufacturers was seriously inflating his study accuracy figures and, to say the least, misleading their management with perhaps some bad decision-making based on faulty study reporting.

Rule #2: Determine what it is you wish to measure and how detailed the results need to be. The more detailed results required – the more observations required. Carefully understand the statistics underlying the work sampling methodology!

DETERMINE YOUR ACTIVITIES (BOTH GENERAL AND SUB-)

Formulate the activity categories (both general and sub-) for the sampling. These categories of work should be designed for ease of observation and be consistent with the objectives (mission) of the study. For Computer-Aided Work Sampling with Microsoft Excel™ (CAWS/E) you should first identify the General Activities followed by the Sub-Activities. One of the many reasons for a ½ to 3-day preliminary work sampling study is to make sure you have identified all the activities you will come across during the duration of the study. An example of the list of General and Sub-Activities we used in a large work sampling study of warehouse activities is shown in Figure 3.

Activity	Description
10	DIRECT PRODUCTIVE WORK
11	Load/Unload Truck
12	Stage
13	Pull
14	Pack/Palletize
15	Transport
16	Testing & Inspection
17	Rework
18	Miscellaneous
20	INDIRECT PRODUCTIVE WORK
21	Walk/Check Materials
22	Speak, "Necessary"
23	Paperwork/Computer
24	Unpack/Repack
25	Miscellaneous
30	NON-PRODUCTIVE WORK
31	Clean-Up
32	Drive/Walk Empty
33	Wait
34	Miscellaneous
40	OUT-OF-AREA
41	Assigned
42	Unknown
50	REST & PERSONAL TIME
51	Scheduled Break
52	Personal Time

Figure 3. Example of Activities Descriptions for a Warehouse CAWS/E Study

DESIGN YOUR WORK SAMPLING STUDY USING THE FULL POWER OF CAWS/E

It is important to design your work sampling study to take full advantage of the powerful sort and select reporting features of CAWS/E. The fact that every observation of a coded work sub-activity is "tagged" with its week, day, shift within the day, hour within the shift, a department (code or supervisor), group within the department, and even the subject (worker or equipment item) provides a superior data base for detailed reporting of the study results. A data collection form used in a 6678-observation work sampling study is shown in Figure 4.

CAWS/E
Computer-Aided Work Sampling with Microsoft Excel
Copyright: Clemson Consulting Clearinghouse Corp.
W=Week; D=Day; S=Shift; H=Hour; C=Supervisor; G=Group
D=Descriptor Code; A=Sub-Activity Code

Observ. #----					>	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10
W	D	S	H	C	G	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A
5	4	1	4	1	9	1	21	2	21	3	14	4	25	5	13	6	14	7	42	8	22				
5	4	1	5	1	9	1	42	2	51	3	14	4	13	5	51	6	51	7	51	8	22				
5	4	1	6	1	9	1	23	2	23	3	23	4	51	5	22	6	23	7	22	8	51				
5	4	1	9	1	9	1	23	2	21	3	42	4	42	5	31	6	31	7	21	8	15				
5	3	1	2	1	1	5	22	8	22	1	22	2	41	4	21	3	12	6	51	7	51				
5	3	1	4	1	1	3	33	4	23	6	23	1	23	2	23	8	12	5	12	7	42				
5	3	1	6	1	1	3	12	6	32	1	23	7	32	2	33	5	12	4	51	8	51				
5	3	1	8	1	1	1	23	3	41	4	41	5	41	6	41	7	41	8	41	2	42				
5	4	1	2	1	8	3	14	4	14	6	14	7	14	8	15	5	41	1	23	2	42				
5	4	1	4	1	8	7	13	5	12	1	23	2	23	4	11	6	11	3	14	8	42				
5	4	1	5	1	8	3	14	4	23	8	23	1	51	2	51	5	51	6	51	7	51				

Figure 4. Example of the Custom Template CAWS/E Spreadsheet

The following data ranges should be kept in mind in designing the study. Remember, all data are **NUMERIC** (no alpha characters allowed):

W - Week: Range from 1 – 99

D - Day: Range from 1 – 7 (recommended 1 for Monday, 2 for Tuesday, etc.)

S - Shift: Range from 1 – 4

H - Hour: Range from 1 – 9

C - Code (or Supervisor or Department): Range from 1 – 99

G - Group (within the Code or Supervisor or Department): Range from 1 – 9

D – Descriptor (to identify the subject who is involved in doing the activity observed): Range from 0 - 9

A - Activity (the code for the Sub-Activity being observed). Range from 11 – 19; 21 – 29; 31 – 39; 41 – 49; 51 – 59; 61 – 69; 71 – 79; 81 – 89; and 91 – 99. This represents a total maximum of 81 different sub-activities which can be observed.

The General Activities 10, 20, 30, 40 etc. contain or subsume the Sub-Activities. General Activities are not used for recording observations.

The industrial engineer can (and should) be creative in the use of these work sampling study parameters. For example, "Shift" (S) does not have to be literally used for "Shift." We have used this parameter to identify the organizational category of the observer. In a warehouse study we used Shift 1 to identify the group of production workers who were observers, Shift 2 was used to identify the warehouse manager, Shift 3 identified the C-FOUR consulting assistant, and finally Shift 4 was used to identify the plant I.E. This was done to identify observational errors and upon which correctional action was taken.

Likewise, we used "Group" (G) to identify the specific production worker who was an observer. There were nine (9) production workers (coded as Groups 1 – 9 within Shift 1) used as study observers. As in the previous case, this was used to identify errors.

The "Descriptor" (D) code was used (in the tire manufacturer's Central Maintenance Study) to identify the job grade of the worker, instead of a specific person.

See Figure 5 for an example of a sorted CAWS/E report by hour of the shift for the warehouse study. Figure 6 shows an example of a sort report-based graphical comparison of six material handling warehouse associates (please note the significant differences).

General Activity	**Obs**	**%**	**LCL %**	**UCL %**	**Sub Activity**	**Obs**	**%**	**LCL %**	**UCL %**
10 DIRECT PRODUCTIVE WORK	272	38.1	34.5	41.8					
					11 Load/Unload Truck	11	1.5	0.6	2.5
					12 Stage	24	3.4	2.0	4.7
					13 Pull	35	4.9	3.3	6.5
					14 Pack/Palletize	107	15.0	12.3	17.7
					15 Transport	61	8.6	6.5	10.7
					16 Testing & Inspection	27	3.8	2.4	5.2
					18 Miscellaneous	7	1.0	0.2	1.7
20 INDIRECT PRODUCTIVE WORK	219	30.7	27.3	34.2					
					21 Walk/Check Mat'ls	25	3.5	2.1	4.9
					22 Speak, "Necessary"	79	11.1	8.7	13.4
					23 Paperwork/Computer	97	13.6	11.0	16.2
					24 Unpack/Repack	7	1.0	0.2	1.7
					25 Miscellaneous	11	1.5	0.6	2.5
30 NON-PRODUCTIVE WORK	130	18.2	15.3	21.1					
					31 Clean-Up	7	1.0	0.2	1.7
					32 Drive/Walk Empty	100	14.0	11.4	16.6
					33 Wait	16	2.2	1.1	3.4
					34 Miscellaneous	7	1.0	0.2	1.7
40 OUT-OF-AREA	66	9.3	7.1	11.4					
					41 Assigned	19	2.7	1.5	3.9
					42 Unknown	47	6.6	4.7	8.5
50 REST & PERSONAL TIME	26	3.6	2.2	5.1					
					51 Scheduled Break	7	1.0	0.2	1.7
					52 Personal Time	19	2.7	1.5	3.9
						713			
Hour	1								

Figure 5. Example of a CAWS/E Report by Hour (Report for just Hour 1 shown here)

Descriptor	Direct Productive Work	Sum of Sub-Activities 22, 32, & 51
3	44.7	22.1
4	41.5	29.6
5	37.7	31.6
6	39.6	32.7
7	32	37.4
8	22.7	45.9

Sub-Activity Number and Description
22 -- Speak, "Necessary"
32 -- Drive/Walk Empty
51 -- Scheduled Break

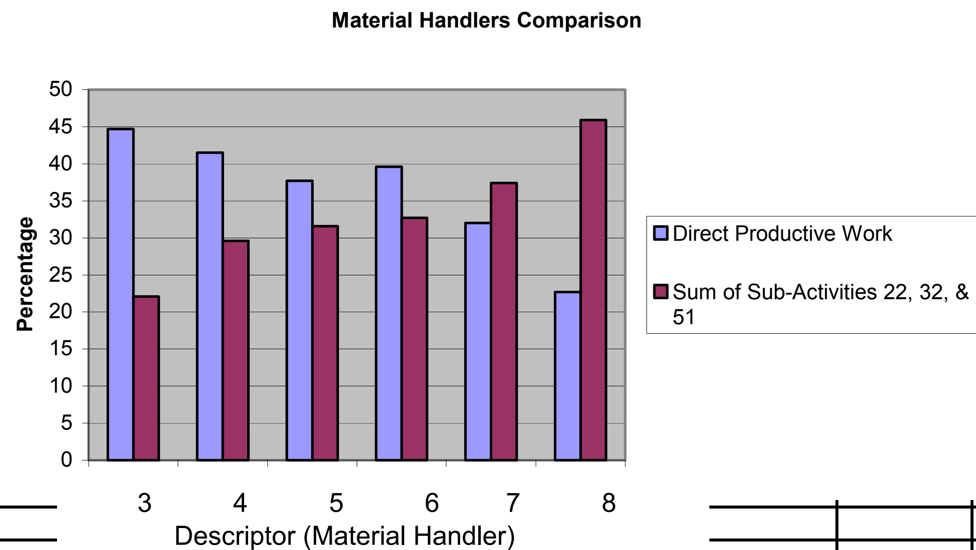


Figure 6. A Sort Report-Based Graphical Comparison of Work Sampling Subjects

Rule #3: Make judicious use of the CAWS/E's study parameters, week, day, shift, hour, code (supervisor or department), group (within the code, supervisor or department), and descriptor. These parameters may be used to generate very valuable sort and select reports of interest to management. Bottom line: keep in mind how you want to select, slice, and dice the data later when you want to report results.

DESIGN THE STUDY USING CAWS MOD I WORK SAMPLING STUDY DESIGNER

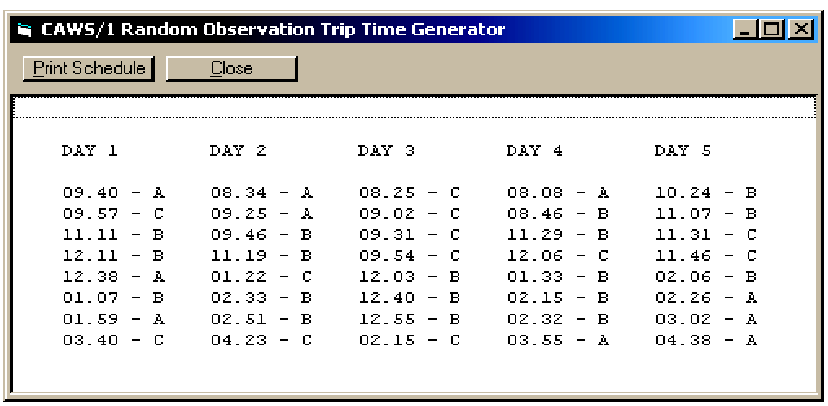
Use CAWS Mod I to help you determine the number of observations and trips you will need to take to collect the appropriate statistical number of observations. Keep in mind the fact that the smallest proportion of time activity along with the smallest work group of interest will determine the number of observations along with the sort and select criteria you wish to employ in reporting.

Rest assured however, that CAWS/E will "keep the analyst honest" since all CAWS/E reports will show the reported proportion of time along with the Upper and Lower Confidence Limits (based on 95.4% confidence limits). So, if you "slice and dice" the data up too much, the results will show the effect of this data dilution in terms of noticeably broadening the control limits!

If you use CAWS Mod I in designing your work sampling study you can generate the random trip times to make your observations. You can even leave out breaks and lunch if all workers use these time periods more or less exactly. We usually leave breaks and lunch <u>in</u> the study in case some workers leave early and come back late from breaks and lunch periods. CAWS Mod I also guarantees that the start of one trip will not interfere with any part of the previous trip. If you specify a trip time of 32 minutes, no two trips will be less than 32 minutes apart.

It is recommended that the trip starting points be chosen randomly, i.e., if there is more than one place an observer can start a trip that the starting points be chosen randomly. It is recommended that a facility layout be drawn showing the various starting points and paths the analyst can take in making his/her tours.

This feature is built into CAWS Mod I and a random letter can be inserted after the random time to denote the random starting point. For example the times 8:23 - A and 9:14 - C means the analyst should start a trip at 8:23 AM and use starting point A, then the next trip starts at 9:14 and the analyst uses starting point C. An example of a random trip schedule is shown in Figure 7.



DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
09.40 - A	08.34 - A	08.25 - C	08.08 - A	10.24 - B
09.57 - C	09.25 - A	09.02 - C	08.46 - B	11.07 - B
11.11 - B	09.46 - B	09.31 - C	11.29 - B	11.31 - C
12.11 - B	11.19 - B	09.54 - C	12.06 - C	11.46 - C
12.38 - A	01.22 - C	12.03 - B	01.33 - B	02.06 - B
01.07 - B	02.33 - B	12.40 - B	02.15 - B	02.26 - A
01.59 - A	02.51 - B	12.55 - B	02.32 - B	03.02 - A
03.40 - C	04.23 - C	02.15 - C	03.55 - A	04.38 - A

Figure 7. Random Trip and Route Generator Report

Rule #4: Use CAWS Mod I to design your study and generate random trip times and route starting points. (Note: Random trip times are not always necessary. If the work itself is random and non-repeating, fixed interval [or systematic] trips are satisfactory.)

SOME OTHER TIPS, TRICKS, AND HELPFUL HINTS

(1) You may experience subject-based bias during the first few days of the study. We have recommended starting the first day of the study on a Wednesday (Day 3 of Week 1). Most bias will "wash out" during Week 1 (the Wednesday through Friday of that week). By making Week 2 the minimum week for data reporting, these first three days of the study can be excluded. If you think it will take the entire Week 1 to wash out subject bias, start the study on a Monday.

(2) Choose regular observation points for making your activity decisions. By even making a taped cross on the floor at these points you help minimize analyst bias in making a decision as to what the worker was doing at the point the analyst sees the worker or operator. When the analyst's foot hits the taped cross on the floor is the instant the decision is made.

(3) Fill out the Excel custom template spreadsheet, "collect.pxl," fields for Week, Day, Shift, Hour, Code (Supervisor or Dept.), Group, and even Descriptor before going out on your observation tour. You can highlight, copy, and paste from one Excel row to the next to make this process even easier. If this is done, the only thing the analyst has to do is to enter the two-digit code for the sub-activity observed. When done, save the file under a different name than "collect.pxl" since that file is read-only.

(4) *Do not wait too long before downloading the data from your Handheld PC to your desktop PC for data analysis.* To help you make this decision you may wish to determine how much data you can afford to lose and not wait any longer than this to download or save your data to a PCMCIA memory card at the very least. PCMCIA memory cards are available for your Handheld PC. Ask us at C-FOUR for more information on these PCMCIA cards. Although this occurrence is rare, H/PCs have locked up and data lost. If this happens (and again, this is rare) make sure you do not lose any more data than you have to! As some "rules of thumb," we recommend saving the data to a PCMCIA memory card every hour and/or downloading the data collection file to the desktop PC every two hours and never less frequently than a half-day.

(5) The videotape, "CAWS/E: Description and Demonstration" (42 minutes), is provided (at no extra charge to CAWS/E clients) for your review and instruction. Reviewing this video once or even twice prior to using CAWS/E is advisable.

(6) The 3-videotape set, "Work Sampling for Labor Productivity Improvement Parts A & B (Videos #7 and #8, total of 64 minutes)" and "Computer-Aided Work Sampling and the Improvement Process" (Video #9, 61 minutes), is available and will be of interest to those who need basic instruction or an instructional refresher in the work sampling methodology. The videotape, "Activity (Work) Sampling," is a short (20 minute) introduction to the technique. Call C-FOUR for more information (864) 624-1234.

(7) If you need additional advice, please contact Carl R. Lindenmeyer, Professor Emeritus of Industrial Engineering, at (864) 624-1234. He will be very pleased to help you with your CAWS/E work sampling study design, conduct, and reporting. This consulting service (via phone, fax, or e-mail) is provided to C-FOUR clients without professional fees or costs of any kind. A charge is made for on-site consultation.