

THE REDESIGN OF THE CURRENT POPULATION SURVEY:  
THE INVESTIGATION INTO ALTERNATE ROTATION PLANS

Robert Tegels and Lawrence S. Cahoon, U.S. Bureau of the Census

## I. INTRODUCTION

The Current Population Survey (CPS) is a multi-stage stratified sample survey of households conducted monthly by the Bureau of the Census for the Bureau of Labor Statistics. The survey collects employment information in order to produce national and state estimates of labor force characteristics for the civilian noninstitutional population.

As the survey objective change over time, the optimal sample rotation pattern may also change. This paper compares three rotation patterns and attempts to determine the optimal one in the face of conflicting objectives. The conclusion is that the survey should retain the current pattern.

The CPS sample originally selected after the 1970 census used a national design; that is, state boundaries were not taken into account in the design. This national design was appropriate at the time, because estimates from the CPS were produced only at the national level. However, in the mid-1970's, more interest was expressed for data by state. In response to this, supplemental sample units were added to the CPS in about half the states in order that annual estimates for every state would meet reliability requirements. These annual estimates were produced using the total state sample; i.e., the national sample plus the supplemental sample. Though in many cases, strata for these state samples were different from those in the national design, other aspects of the state design, in particular, the rotation plan, remained the same as those used in the national design.

The current CPS design uses a rotating sample in which a panel of households called a rotation group is interviewed for four months, dropped from the sample for eight months, then interviewed for another four months. Figure 1 illustrates this rotation plan. The figure designates with an "x", those panels which are to be interviewed in each month. Each month, three-fourths of the sample from the previous month is interviewed, one-eighth of the sample is interviewed for the first time, and one-eighth of the sample is resuming interviews after being out of sample for eight months.

Also, each month, fifty percent of the households being interviewed were interviewed in the same month of the previous year, and the other fifty percent will be interviewed in the same month the next year. Thus, the sample is divided into eight roughly equal parts. One rotation group is made up of all households being interviewed for the first time. Another is made up of all households being interviewed for the second time, and so on. As an example, look at the first February in Figure 1. Panel 17 is being interviewed for the first time. Panel 5 is resuming interview after being out of sample for eight months. Panels 2, 3, 4, 14, 15, and 16 were interviewed in the preceding month. Panels 14, 15, 16, and 17 will be interviewed one year later in February, and Panels 2, 3, 4, and 5 were

interviewed one year earlier in February. This rotation plan, called a 4-8-4 plan, increases reliability on estimates of month-to-month change and year-to-year change, relative to taking an independent sample each month.

The CPS is redesigned every ten years to take advantage of data available from the decennial census, to apply new statistical methodology, and to adapt the survey to changing goals. With the current emphasis on annual state data, it may be desirable to change the rotation plan. The present 4-8-4 rotation plan was chosen as optimal at a time when national estimates of month-to-month changes were the major goals of the CPS. However, since annual estimates become more reliable as there is less overlap among the monthly samples, it may be desirable to change the CPS rotation plan to one which has less month-to-month overlap, although some overlap is still necessary because national estimates of month-to-month change remain important. This study concentrated on one alternative rotation plan, a 3-9-3, and a variation of it, the 3-9-3-9-3. Under the 3-9-3 plan, a household is in sample for three months, out of sample for nine months, then returns to sample for three more months of interview. The 3-9-3-9-3 plan calls for three additional months of interviewing after another nine month period out of sample. Other rotation plans were also investigated, but didn't appear to be as promising as the 3-9-3.

## II. ANALYSIS

The objective was to determine which rotation pattern is preferable from a cost-variance standpoint for estimating both national month-to-month change estimates and state annual estimates. Cost estimates for each of the rotation plans prepared by the staff at the Census Bureau which is in charge of sample selection and maintenance and interviewing. These estimates assumed that except for the rotation plan, all aspects of the sample design would remain as they are now. However, changing the rotation plan would necessitate some changes in the sample operations, such as interviewer workload size, percentage of telephone interviews, updating of household control information, total number of households selected for the life of the survey, etc. The conclusion reached was that for the same monthly sample size, a 3-9-3 plan would cost seven percent more than the 4-8-4. (The sample selection and maintenance would cost 23 percent more and the interviewing costs would be six percent more.) The 3-9-3-9-3 plan would cost four percent more than the 4-8-4 (about the same for selection and maintenance, but four percent more for interviewing).

There are a couple of reasons for the increased costs. The 3-9-3 plan is more costly because more sample households are required over the life of the survey. The 3-9-3 plan obtains six interviews from each household, while the 4-8-4 plan gets eight. The 3-9-3-9-3 plan is more expensive than the 4-8-4 primarily because households must be kept track of over a longer period of time.

Also, the 3-9-3 and 3-9-3-9-3 plans would require more personal interviews. The current CPS interviewing procedures call for personal visits for all households being interviewed for the first time, or resuming interviews after a period out of sample. Other households may be interviewed by telephone. Therefore, the 3-9-3 and 3-9-3-9-3 plans would require that one-third of the interviews be personal visits, while the 4-8-4 plan would require only one-fourth of the interviews be personal visits. These estimates assume that the number of households interviewed each month would be the same under each rotation plan. This implies that a panel under the 3-9-3 would be 4/3 as large as one under the 4-8-4 plan, since the 3-9-3 plan would have six panels in sample each month while the 4-8-4 plan would have eight panels each month. Similarly, a panel under the 3-9-3-9-3 plan would be 8/9 as large as a 4-8-4 panel, because the 3-9-3-9-3 plan has nine panels in sample each month.

Variances for this study were calculated directly from one year of CPS sample data. <sup>1/</sup> For each month, variances and covariances were estimated between all panels in sample for that month for the types of estimates now produced. For example, in the first January in Figure 1, the variance on number of employed was computed for each of panels 1, 2, 3, 4, 13, 14, 15, and 16, and all the covariances between these panels were computed. This was done for each of 12 months, so that a variance on the annual average could also be computed. These computations yielded the appropriate variances for the 4-8-4 rotation plan.

Variances for the 3-9-3 plan were obtained by noting that if the panels which are in sample for the fourth and eighth time under the 4-8-4 plan are ignored, then the remaining panels behave like a 3-9-3 plan. This can be seen by looking at Figure 1, while ignoring the x's which are circled. Therefore, to get the 3-9-3 variance for the first January, the variances and covariances between panels 2, 3, 4, 14, 15, and 16 would have to be summed. Using the twelve months of data in this way, monthly and annual variances for the 3-9-3 plan were calculated. Remembering that each panel under the 3-9-3 plan needs to be 4/3 larger than the 4-8-4 panels, the 3-9-3 variances must be adjusted so that they reflect the same total monthly sample size as the 4-8-4 rotation plans. Note that for monthly and annual data, the variances for the 3-9-3-9-3 plan will be the same as those for the 3-9-3 plan because both plans have the same overlap pattern within a given year.

As stated above, the two primary concerns for the current CPS are national estimates of month-to-month change and state estimates of annual averages. For a given monthly sample size, switching to a 3-9-3 or 3-9-3-9-3 rotation pattern would hurt the reliability of national month-to-month change estimates and improve the reliability of state annual estimates because it has less month-to-month overlap.

The Bureau of Labor Statistics has stated two primary reliability requirements. One is that the present reliability on national estimates of month-to-month change in employment is to be maintained. This has been interpreted to mean that the existing reliability under the national sample (without the state supplement) is to be maintained. The second reliability requirement is that the

present reliability of annual state estimates be maintained. This requires that the reliability under the total sample (national sample plus state supplement) be maintained. Therefore, because of the decreasing month-to-month overlap, a switch to a 3-9-3 or 3-9-3-9-3 rotation pattern would necessitate an increase in the national sample size in order to maintain the reliability of the national month-to-month change estimates, but would also allow a decrease in the total state sample size and still meet the reliability requirement on state annual estimates.

In this analysis, three scenarios are looked at. In the first, the present reliability is maintained on national estimates of change for both employment and unemployment and on state annual estimates for level of unemployment. The second scenario assumes the reliability on state annual estimates of unemployment and national estimates of change in unemployment will be maintained, but permits the reliability of national estimates of change in employment to decline. The third scenario maintains only the reliability of the state annual estimates of level of unemployment, but permits the reliability of national estimates of change for both employment and unemployment to decline. <sup>2/</sup>

The variance computations indicated above have shown that a 3-9-3 or 3-9-3-9-3 rotation plan will reduce the variance of an annual average estimate of unemployed by 14 percent, when compared to the present 4-8-4 plan. Also, for the same monthly sample size, a 3-9-3 pattern will cost 7 percent more than the 4-8-4 pattern and a 3-9-3-9-3 pattern will cost 4 percent more. Also, preliminary estimates have shown that the switch to a 3-9-3 plan would cause an increase in variance on national month-to-month change estimates of 7 percent for unemployment and 20 percent for employment. Thus, under the first scenario, the required sample for the 3-9-3 plan will be approximately 20 percent larger than the current national sample size in each state in order to retain the reliability on these national estimates. Assuming that the current total state sample yields the desired reliability for annual state estimates of unemployed, then, with a switch to a 3-9-3 rotation system, a sample about 14 percent smaller than the present total state sample is needed in each state to retain this reliability. (The 14 percent reduction in variance for annual estimates is based on data from the whole country, not the individual states. Therefore, the reduction in variance for any one particular state may or may not be 14 percent, but the reduction in variance averaged over all the states should be about 14 percent.) These same figures also hold for the 3-9-3-9-3 plan since it has the same month-to-month and yearly overlap pattern as the 3-9-3 plan. The actual sample size needed in a given state then would be the larger of these two figures.

The attached Table 1 shows the CPS sample size by state for October 1980. If there is a switch to the 3-9-3 rotation pattern, then there must be an increase in the national sample sizes by 20 percent, and decreases in the total state sample sizes by 14 percent. These values are also given in columns 4 and 3 of the table. In order to have reliable annual state estimates for unemployment and national month-to-month change estimates for employment and unemployment, the larger of these

two sample sizes for each state must be chosen. These values are given in column 5 of the table. Thus, a sample of size 81,585 households is needed for the 3-9-3 plan and 78,004 for the 4-8-4 plan, an increase of 5 percent. Since the 3-9-3 plan also costs 7 percent more than the 4-8-4 for the same sample size, the 3-9-3 plan is much more expensive.

The 3-9-3-9-3 pattern will also require a sample 5 percent greater than the 4-8-4 plan to satisfy both the reliability requirements. It will also be more expensive since it costs four percent more than the 4-8-4 given the same sample size.

Columns 6 and 7 of Table 1 correspond to the second scenario in which we allow less reliable estimates of national change in employment. If we switch to the 3-9-3 rotation pattern, we must increase the national sample sizes by 7 percent, and decrease the total state sample sizes by 14 percent in order to have reliable annual state estimates and national month-to-month change estimates of unemployment. This will result in the variances of national change estimates for employment increasing by about 12 percent. Thus, we have a sample size of 75,584 households for the 3-9-3 plan and 78,004 for the 4-8-4 plan, a decrease of about 3 percent. Since the 3-9-3 plan costs 7 percent more (given the same sample size), the 3-9-3 plan would appear to be inferior to the 4-8-4 plan.

Scenario two for the 3-9-3-9-3 plan shows a 3 percent decrease in sample size with a 4 percent increase in cost (given equal sample sizes) relative to the 4-8-4 plan, so the 4-8-4 plan still appears to be marginally better.

Column 8 of Table 1 shows the third analysis. In this scenario, we maintain the present reliability of state annual estimates, but permit the national month-to-month change estimates to become less reliable, i.e., we do not increase the national sample size to make up for the lower month-to-month overlap under the 3-9-3 plan. Under these assumptions, the 3-9-3 plan requires 72,562 sample households, a decrease of about 7 percent from the 4-8-4 plan. Since the 3-9-3 plan costs 7 percent more per sample unit, it again appears that the 4-8-4 plan is better because, for about the same cost, we would not lose the reliability of the national month-to-month change estimates.

Under the third scenario for the 3-9-3-9-3 pattern, we have a 7 percent decrease in sample size with only a 4 percent increase in cost per sample unit, so the 3-9-3-9-3 plan appears to save money. However, this savings must be balanced against the loss in reliability of month-to-month change estimates.

Table 2 summarizes these options and shows the approximate ratio of the cost of the alternative plans to the 4-8-4 plan under the three scenarios. We have also considered other rotation plans (e.g., 2-2-2-6-2-2-2), but theoretical work with existing data has led us to believe that these others would not perform as well as the 3-9-3 on annual estimates.

### III. RECOMMENDATIONS

The above analysis indicates that a 4-8-4 rotation pattern is preferable. In addition to the factors above, efficiencies in state estimates built into the redesign as a result of our re-

search into stratification and within PSU sampling would tend to favor a 4-8-4 rotation system over a 3-9-3 or 3-9-3-9-3 rotation system. For example, if the stratification for state estimates was optimal rather than having the current inefficiencies, the amount of sample added to improve state estimates would be less than presently is the case. This would make less sample available where the efficiencies of the 3-9-3 or 3-9-3-9-3 rotation plans could be used. This, in turn, favors the 4-8-4 rotation system. Also, concern has been expressed about the 3-9-3-9-3 rotation plan because respondents would be in sample for a longer time period. In view of this analysis, the recommendation made was to remain with the present 4-8-4 rotation system. Since we would still like to improve the reliability of annual estimates, we will now concentrate our research on improving the estimation procedure using a 4-8-4 rotation plan.

\* \* \* \* \*

### FOOTNOTES

<sup>1</sup> Variances for the CPS are computed using the Keyfitz method of half sample differences. (See Nathan Keyfitz, "Estimates of Sampling Variance Where Two Units are Selected from Each Stratum," *Journal of the American Statistical Association*, No. 52, (1957), pp. 503-510). Details as to how this procedure is applied to CPS can be obtained from "The Current Population Survey: Design and Methodology," U.S. Department of Commerce, Technical Paper 40.

<sup>2</sup> The second and third scenarios do not maintain the existing reliability of national monthly change estimates in employment, as desired by BLS. We wanted to include in our research the cost implications for maintaining the present national reliability.

### ACKNOWLEDGEMENTS

The authors wish to acknowledge George Train for programming the variance computations which were the basis of this paper. Special thanks to Linda Sinanian for her patience in typing several drafts and the final copy of this report.

Figure 1:

Rotation Chart for CPS Rotation Group

		Panel																																
Month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
Jan.		X	X	X										X	X	X	X																	
Feb.		X	X	X										X	X	X	X																	
Mar.		X	X	X										X	X	X	X																	
Apr.		X	X	X										X	X	X	X																	
May		X	X	X										X	X	X	X																	
June		X	X	X										X	X	X	X																	
July		X	X	X	X									X	X	X	X																	
Aug.		X	X	X	X									X	X	X	X																	
Sep.		X	X	X	X									X	X	X	X																	
Oct.		X	X	X	X									X	X	X	X																	
Nov.		X	X	X	X									X	X	X	X																	
Dec.		X	X	X	X									X	X	X	X																	
Jan.		X	X	X	X									X	X	X	X																	
Feb.		X	X	X	X									X	X	X	X																	
Mar.		X	X	X	X									X	X	X	X																	
Apr.		X	X	X	X									X	X	X	X																	

Table 1.

COMPARISON OF REQUIRED SAMPLE SIZES BY STATE  
FOR THE 4-8-4, 3-9-3, and 3-9-3-9-3 ROTATION  
SYSTEMS UNDER THREE SCENARIOS

State	Current Sample Sizes (Oct. 1980)		Total State Sample Less 14 Percent (3)	Scenario One		Scenario Two		Scenario Three
	National	Total State		National Sample Plus 20 Percent (4)	Required Sample for 3-9-3 1/ Plan (Maximum of columns 3 & 4) (5)	National Sample Plus 7 Percent (6)	Required Sample for 3-9-3 1/ Plan (Maximum of columns 3 & 6) (7)	Required Sample for 3-9-3 1/ Plan (Maximum of columns 1 & 3) (8)
	(1)	(2)		(3)	(4)	(5)	(6)	(7)
UNITED STATES	56277	78004			81585		75584	72562
Alabama	1067	1235	1062	1280	1280	1142	1142	1067
Alaska	79	1065	916	95	916	85	916	916
Arizona	821	1278	1099	985	1099	878	1099	1099
Arkansas	617	1153	992	740	992	660	992	992
California	5984	5984	5146	7181	7181	6403	6403	5984
Colorado	698	1181	1016	838	1016	747	1016	1016
Connecticut	797	847	728	956	956	853	853	797
Delaware	134	865	744	161	744	143	744	744
District of Columbia	189	968	832	227	832	202	832	832
Florida	2575	2575	2215	3090	3090	2755	2755	2575
Georgia	1337	1337	1150	1604	1604	1431	1431	1337
Hawaii	165	759	653	198	653	177	653	653
Idaho	185	1257	1081	222	1081	198	1081	1081
Illinois	2684	2684	2308	3221	3221	2872	2872	2684
Indiana	1466	1466	1261	1759	1759	1569	1569	1466
Iowa	619	1218	1047	743	1047	662	1047	1047
Kansas	591	1132	974	709	974	632	974	974
Kentucky	968	1216	1046	1162	1162	1036	1046	1046
Louisiana	1137	1137	978	1364	1364	1217	1217	1137
Maine	487	1248	1073	584	1073	521	1073	1073
Maryland	1011	1060	912	1213	1213	1082	1082	1011
Massachusetts	1332	1567	1348	1598	1598	1425	1425	1348
Michigan	2417	2417	2079	2900	2900	2586	2586	2417
Minnesota	1012	1228	1056	1214	1214	1083	1083	1056
Mississippi	486	1192	1025	583	1025	520	1025	1025
Missouri	1371	1371	1179	1645	1645	1467	1467	1371
Montana	199	1240	1066	239	1066	213	1066	1066
Nebraska	385	1099	945	462	945	412	945	945
Nevada	104	1372	1180	125	1180	111	1180	1180
New Hampshire	309	1040	894	371	894	331	894	894
New Jersey	1829	1829	1573	2195	2195	1957	1957	1829
New Mexico	232	1151	990	278	990	248	990	990
New York	4376	4505	3874	5251	5251	4682	4682	4376
North Carolina	1284	1284	1104	1541	1541	1374	1374	1284
North Dakota	164	1277	1098	197	1098	175	1098	1098
Ohio	2674	2674	2300	3209	3209	2861	2861	2674
Oklahoma	726	1230	1058	871	1058	777	1058	1058
Oregon	922	1307	1124	1106	1124	987	1124	1124
Pennsylvania	2975	2975	2559	3570	3570	3183	3183	2975
Rhode Island	248	904	777	298	777	265	777	777
South Carolina	693	908	781	832	832	742	781	781
South Dakota	207	1282	1103	248	1103	221	1103	1103
Tennessee	1008	1022	879	1210	1210	1079	1079	1008
Texas	3315	3315	2851	3978	3978	3547	3547	3315
Utah	307	1305	1122	368	1122	328	1122	1122
Vermont	152	1055	907	182	907	163	907	907
Virginia	1240	1240	1066	1488	1488	1327	1327	1240
Washington	997	1255	1079	1196	1196	1067	1079	1079
West Virginia	446	1133	974	535	974	477	974	974
Wisconsin	1113	1113	957	1336	1336	1191	1191	1113
Wyoming	143	1049	902	172	902	153	902	902

1/ These sample sizes also hold for the 3-9-3-9-3 rotation plan.

Table 2.

RATIOS OF COSTS OF ALTERNATIVE ROTATION PLANS TO  
THE 4-8-4 ROTATION PLAN FOR THREE SCENARIOS

<u>Scenario</u>	<u>Alternative Rotation Plan</u>	
	<u>3-9-3</u> <sup>1/</sup>	<u>3-9-3-9-3</u> <sup>1/</sup>
1. Maintain Reliability of Both National Change Estimates of Employed and Unemployed and State Annual Estimates of Unemployed	(1.05)(1.07) = 1.12	(1.05)(1.04) = 1.09
2. Maintain Reliability of State Annual and National Change in Unemployment <u>2/</u>	(0.97)(1.07) = 1.04	(0.97)(1.04) = 1.01
3. Maintain Reliability of Only State Annual Estimates <u>3/</u>	(0.93)(1.07) = 1.00	(0.93)(1.04) = 0.97

---

1/ The first number in the product is the ratio of sample size for the alternative plan to the 4-8-4 from Tables 1-3. The second number is the ratio of the cost of the alternative to the 4-8-4, given the same sample size. Therefore, the product of the two numbers is the ratio of the cost of the alternative to the 4-8-4 under the different scenarios.

2/ Under this scenario, the reliability of National change estimates of Employment will decline by about 12 percent using the alternative rotation plans.

3/ Under this scenario, the reliability of National change estimates of Civilian Labor Force will decline by about 20 percent and those of Unemployment by about 7 percent under the alternative rotation plans.