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BDX-613-885

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ECONOMIC IMPROVEMENT OF
INVENTORY SAMPLING

C. D. Rinker, Project Leader

Internal Distribution April 1973

Prepared for the
United States Atomic Energy Commission
Under Contract Number AT(29-1)-613 USAEC

**Kansas City
Division**

S1628

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**ECONOMIC IMPROVEMENT OF
INVENTORY SAMPLING**

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Internal Distribution April 1973

Project Leader:
C. D. Rinker
Department 114

Topical Report

Technical Communications

**Kansas City
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ECONOMIC IMPROVEMENT OF INVENTORY SAMPLING

BDX-613-855, UNCLASSIFIED Topical Report, Internal Distribution April 1973

Prepared by C. D. Rinker, D/114

Improved methods of inventory sampling to determine record accuracy are discussed. Application is made to Central Stores and Test Equipment Stores inventories at Bendix Kansas City. An improved sampling procedure is outlined which improves efficiency by 24 percent. Similar economic savings are possible for any stratified inventory in which the statistical variance among the strata differ significantly.

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THE BENDIX CORPORATION

KANSAS CITY DIVISION

KANSAS CITY, MISSOURI

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SUMMARY

This study investigates the application of sampling methodology to Bendix stores inventories. The subject inventories are those of Central Stores and Test Equipment Stores which, for accounting and record keeping purposes, are stratified. The Central Stores inventory is stratified by commodity and the Test Equipment Stores by unit cost. In an earlier study of the Central Stores inventory strictly random sampling and sampling based on stratum size alone were considered. The present study applies the principle of stratum sample size proportional to stratum size and standard deviation.

Comparative analysis has shown that use of the new methodology improves sampling efficiency by 24 percent. The sample sizes necessary for both Central and Test Equipment Stores were determined that permit estimates of the dollar difference between account records and physical inventory within less than 5 percent of the inventory value with 95 percent confidence.

Plans have been made to use yearly sample results to adjust estimates of strata standard deviations and, in turn, to adjust strata sample sizes for the following year. Application of the theory to in-process product inventory is also planned.

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DISCUSSION

SCOPE AND PURPOSE

The present study is limited to inventoried items in nonproductive stores, that is, stores in which the items are not in the bill-of-material for the product. Central Stores and Test Equipment Stores are treated similarly but separately.

The purpose of the study was to provide a more economical means of adjusting stores accounts in line with physical inventory. The initial objective was to estimate dollar difference within 5 percent or less of total inventory value with 95 percent confidence.

PRIOR WORK

Stores accounts are adjusted yearly to bring them in line with the physical inventory. The reasons that account records differ from physical inventories have not been investigated. Accounts are adjusted by changing the dollar book value of inventory. Prior to 1971, the dollar differences were determined by a 100 percent physical inventory of stores items. During 1971 a pilot study conducted by The Management Science Department resulted in the use of sampling to estimate dollar differences for Central Stores inventory. Data collected during the 1970 total inventory were used as a basis for sample sizes. The resultant sample sizes were determined by stratum size or expanded to a minimum percentage of stratum size, on an intuitive basis, to provide assurance in dollar difference estimates.

No prior work has been attempted with Test Equipment Stores inventory.

ACTIVITY

Central Stores has historically been stratified by commodity groups for accounting purposes. The number of items and total dollar value in each group remains relatively constant from year to year. An item in stores has a unique part number. The number of units of a given item will vary during the year depending on usage and replenishment. Each unit has an associated unit price which is multiplied by the number of units to provide the item value. Table 1 displays the results from the 1970 total physical inventory. The results exclude items with values exceeding \$200 and items classified as "sensitive." Excluded items will be subjected to a 100 percent physical inventory as a matter of policy.

Table 1. Central Stores Population Data--Fiscal Year 1970

Commodity Group Identification	Number of Items	Average Dollar Value Per Item	Average Dollar Difference*	Statistical Variance
9401	151	47.40	-0.166	27.15
9402	7,274	44.58	+0.259	60.16
9403	93	81.36	-0.140	259.90
9404	761	51.60	-0.848	105.93
9405	2,278	31.92	-0.065	119.76
9406	1,041	28.13	+0.000	6.44
9407	4,362	25.00	-0.103	28.32
9408	9	13.39	-0.667	4.00
9411	89	45.19	-1.292	68.07
9412	63	48.34	+0.762	1028.54
9413	2,315	14.30	+0.031	3.50
9414	181	32.05	-1.823	97.90
9415	856	52.86	-0.557	209.77
Total	19,473	34.57	-0.010	63.01
*Difference between item record value and physical inventory.				

Test Equipment Stores are stratified on a unit cost basis. Table 2 displays the results from the 1971 total physical inventory.

Total Sample Size

The historical data presented was assumed representative of current stores, and the frequency distribution of dollar differences was assumed to follow a normal distribution. In an earlier study it was shown that confidence limits computed without the normal distribution assumption vary only slightly from computations based on the assumption.

The first approach to sampling from a stratified population is to estimate the total sample size and then allocate items to each stratum proportionately. Such an approach was utilized for the 1971 Central Stores sample with a minimum 10 percent from each stratum. The estimated total sample size is computed from Equation 1.

$$n = (1.96 \sigma / 0.05C)^2 \quad (1)$$

where

n = Total sample size;

σ = Total population standard deviation of dollar differences;

C = Average item value for the total population;

1.96 = Number of standard deviations providing 95 percent confidence (under the normal distribution assumption); and

0.05 = 5 percent initial objective for precision of estimate.

Neyman Sampling

An efficient distribution of the total estimated sample size, n , among the several groups provides a smaller confidence band than the required 5 percent. The reason for the smaller confidence band is that a better distribution among the groups provides an estimator with smaller statistical variance than does the strictly random sample from the total population.

Previous experience with stratified sampling has shown that Neyman sampling provides a more efficient sampling technique.* In Neyman sampling the sample size in a stratum is not only proportional to the size of that stratum (N_1) but

*W. E. Deming, "Allocation in Stratified Sampling," Chapter 6 in Some Theory of Sampling. New York: John Wiley & Sons, 1950.

Table 2. Test Equipment Stores Population Data--Fiscal Year 1971

Unit Cost Per Group	Number of Items	Average Dollar Value Per Item	Average Dollar Difference*	Statistical Variance
0.001 to 0.050	430	16.04	-0.953	48.62
0.051 to 0.100	235	17.30	-0.085	31.21
0.101 to 0.150	240	19.24	-0.346	19.67
0.151 to 0.200	85	22.23	0.000	1.13
0.201 to 0.300	140	24.92	-0.571	96.46
0.301 to 0.400	175	16.60	-1.400	246.05
0.401 to 0.500	96	21.29	+0.198	17.60
0.501 to 0.750	183	22.79	-0.169	13.85
0.751 to 1.000	170	29.63	+0.106	5.67
1.001 to 1.500	260	32.11	-0.038	14.63
1.501 to 2.000	170	42.25	-0.418	10.37
2.001 to 3.000	220	46.33	-0.991	110.05
3.001 to 4.000	175	47.69	-0.354	20.21
4.001 to 5.000	130	46.68	-2.100	386.41
5.001 to 7.500	225	61.53	-0.364	81.87
7.501 to 9.250	110	71.57	+0.309	31.92
9.251 to 11.000	64	75.65	+1.813	91.90
11.001 to 19.000	152	72.56	-1.533	493.16
19.001 to 66.000	240	94.56	-0.667	255.89
66.001 to - - -	180	113.09	+0.411	211.59
Total	3,680	42.36	-0.467	103.87
*Difference between item record value and physical inventory.				

also proportional to the standard deviation of the item cost differences in that stratum (i). Thus the sample size for group i is computed as shown in Equation 2.

$$n_i = \frac{nN_i\sigma_i}{\sum_i N_i\sigma_i} \quad (2)$$

where

n_i = Sample size for group i,

n = Estimated total sample size,

N_i = Population size of group i, and

σ_i = Standard deviation of item cost differences of group i.

The estimated total sample size is allocated to groups based on Neyman sampling. The values of n_i are always rounded up; that is, if the calculated value of n_i were 4.12, a sample of size 5 is used.

Application of Neyman Sampling

As previously noted, there are year-to-year changes in the number of items within a group. Prior to the determination of sample sizes, the total inventory record is reviewed and the group size and average item value determined. For Test Equipment Stores, the group sizes (number of items in group) are shown in the column labeled N in Table 3. The values n are the sample sizes resulting by use of Equation 1 followed by Equation 2.

A comparison of sampling efficiency gave the following results.

- Random samples of 112 items from the total population results in a standard deviation (of the mean dollar difference) of \$3,052.
- Total sample size of 112 items allocated to each group based on the number of items in the group results in a standard deviation of \$2,797.
- Total sample size of 112 items allocated by use of Equation 2 results in a standard deviation of \$2,330.

Thus a 24 percent improvement in sampling efficiency is obtained by use of Equation 2 rather than by strictly random sampling. A 17 percent improvement is obtained by Equation 2 over allocation based on group size alone.

Table 3. Test Equipment Stores Sample Sizes

Unit Cost Per Group	N*	n**
0.001 to 0.050	449	14
0.051 to 0.100	231	6
0.101 to 0.150	240	5
0.151 to 0.200	83	1
0.201 to 0.300	141	6
0.301 to 0.400	165	11
0.401 to 0.500	101	2
0.501 to 0.750	177	3
0.751 to 1.000	168	2
1.001 to 1.500	257	5
1.501 to 2.000	169	3
2.001 to 3.000	200	9
3.001 to 4.000	142	3
4.001 to 5.000	103	9
5.001 to 7.500	148	6
7.501 to 9.250	67	2
9.251 to 11.000	40	2
11.001 to 19.000	99	10
19.001 to 66.000	143	10
66.001 to - - - -	46	3
Total	3169	112
*Number of items in group. **Number of samples.		

The sample sizes in Table 3 give the following confidence values.

- Ninety-five percent confidence that the true value of the difference is within \$4,600 of the computed value.
- Fifty percent confidence that the true value of the difference is within \$1,600 of the computed value.

Since five percent of the inventory value, based on 1971 data, was computed as \$6,700, the sample sizes in Table 3 more than meet the initial confidence criterion.

The four sample sizes given for Central Stores groups are shown in Table 4. The confidence limits on the value of the dollar differences for each sample size are as follows.

Sample Size	Dollar Value With 95 Percent Confidence	Dollar Value With 50 Percent Confidence
207	19,100	6,600
306	15,500	5,300
406	13,400	4,600
506	12,000	4,100

Since five percent of the inventory value, based on 1970 data, was computed as \$32,800, all of the above sample sizes more than meet the initial confidence criterion.

ACCOMPLISHMENTS

A more efficient method of sampling has been applied to determine differences between the dollar value of account records and actual physical inventory value. The increase in efficiency has been calculated at 24 percent. The method used to obtain increased efficiency is Neyman sampling which bases the sample size in each stratum of a stratified population on the size of the stratum and the standard deviation of the parameter being measured. A method of adjusting the historical standard deviation based on the latest sample should be developed to aid in future sample size determinations.

Table 4. Central Stores Sample Sizes

Commodity Group Identification	N*	n**			
		Sample 1	Sample 2	Sample 3	Sample 4
9401	151	2	2	3	3
9402	7274	82	123	163	204
9403	93	3	4	5	6
9404	761	12	17	23	29
9405	2278	36	54	72	90
9406	1041	4	6	8	10
9407	4362	34	51	67	84
9408	9	1	1	1	1
9411	89	2	2	3	3
9412	63	3	5	6	8
9413	2315	7	10	13	16
9414	181	3	4	6	7
9415	856	18	27	36	45
Total	19473	207	306	406	506
*Number of items in group. **Number of samples.					