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# Statistical sampling, an untapped financial management tool

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# *An Untapped Financial Management Tool*

# statistical sampling

By H. JUSTIN DAVIDSON, *Chicago Office*

I AM going to talk this afternoon about a relatively new approach to problems of accounting and management control—the statistical approach. This is an approach to accounting problems which has found growing acceptance within government and business during the past ten years. It is an approach which I am certain that you will hear more about during the next ten years.

The discipline of statistics includes a great many methods and procedures, all of which are related to the growing body of mathematical techniques being used today in the operations research approach to the decision-making problems of management. This afternoon, I am going to talk in large part, however, about a particular phase of the statistical approach—statistical sampling. I am going to talk about this particular phase because it is a part of statistical theory which has had immediate application to many problems of accounting and management control in both business and government.

Before discussing with you some of the proven and potential applications of statistical sampling, I would like to have you consider with me the nature of statistical sampling. What is statistical sampling? How does it differ from ordinary sampling methods?

As individuals, we are all familiar with every-day uses of sampling. We test drive a new car. We skim the content of a professional article, or we sample the quality of a bottle of bourbon. In addition to such personal uses, sampling methods are familiar for their daily use in a variety of business situations. We test check the quality of incoming or outgoing products. We check the validity of accounting information, on something less than 100 per cent basis. We often develop special management information by sampling of one kind or another.

The very familiarity of every-day sampling techniques presents, however, certain problems when speaking of *statistical* sampling. In many respects, statistical sampling is different from ordinary sampling on a judgment basis. For this reason I want first to explore with you the kinds of statistical sampling and how statistical sampling differs from ordinary sampling methods.

Under the general heading of statistical sampling, we find three related techniques. The first and most general of these techniques is called survey sampling. The ob-

## EXHIBIT 1

# *Hypothetical Universe of 100 Vouchers*

| *Voucher number* | *Amount* | *Voucher number* | *Amount* | *Voucher number* | *Amount* | *Voucher number* | *Amount* |
|---|---|---|---|---|---|---|---|
| 00 | $ 1.65 | 25 | $16.01 | 50 | $12.52 | 75 | $19.28 |
| 01 | 11.87 | 26 | 21.06 | 51 | 14.54 | 76 | 17.94 |
| 02 | 11.18 | 27 | 23.38 | 52 | 15.12 | 77 | 19.93 |
| 03 | 11.32 | 28 | 16.32 | 53 | 20.57 | 78 | 15.98 |
| 04 | 10.16 | 29 | 21.54 | 54 | 18.36 | 79 | 22.50 |
| 05 | 4.15 | 30 | 3.65 | 55 | 21.27 | 80 | 13.98 |
| 06 | 12.35 | 31 | 17.69 | 56 | 23.57 | 81 | 16.36 |
| 07 | 7.89 | 32 | 27.14 | 57 | 24.40 | 82 | 24.27 |
| 08 | 12.74 | 33 | 21.60 | 58 | 25.08 | 83 | 24.52 |
| 09 | 6.86 | 34 | 25.30 | 59 | 17.48 | 84 | 27.20 |
| 10 | 5.08 | 35 | 22.34 | 60 | 8.95 | 85 | 18.77 |
| 11 | 21.18 | 36 | 19.88 | 61 | 26.89 | 86 | 19.33 |
| 12 | 21.90 | 37 | 21.84 | 62 | 18.59 | 87 | 24.05 |
| 13 | 19.98 | 38 | 25.00 | 63 | 26.68 | 88 | 18.27 |
| 14 | 23.23 | 39 | 22.28 | 64 | 18.70 | 89 | 24.40 |
| 15 | 23.60 | 40 | 13.18 | 65 | 27.58 | 90 | 13.69 |
| 16 | 19.04 | 41 | 18.85 | 66 | 18.86 | 91 | 31.01 |
| 17 | 23.33 | 42 | 21.04 | 67 | 26.96 | 92 | 32.08 |
| 18 | 22.06 | 43 | 20.56 | 68 | 24.45 | 93 | 27.63 |
| 19 | 17.84 | 44 | 25.38 | 69 | 16.76 | 94 | 29.41 |
| 20 | 11.74 | 45 | 24.20 | 70 | 11.90 | 95 | 33.68 |
| 21 | 16.64 | 46 | 22.26 | 71 | 22.04 | 96 | 31.96 |
| 22 | 16.63 | 47 | 23.85 | 72 | 24.62 | 97 | 28.36 |
| 23 | 24.25 | 48 | 18.50 | 73 | 25.78 | 98 | 33.41 |
| 24 | 21.76 | 49 | 19.97 | 74 | 16.01 | 99 | 28.40 |

**Total Value of 100 Vouchers: $1,995.34**
**Average Value of 100 Vouchers: $19.95**

*Comments on Exhibit 1:* This exhibit lists a hypothetical universe of 100 vouchers which I will talk about for illustrative purposes. This particular illustration of a universe is simplified in that it is small compared to the typical universe encountered.

## EXHIBIT 2

# *Three Judgment Samples*

| *Judgment Sample 1* | | *Judgment Sample 2* | | *Judgment Sample 3* | |
|---|---|---|---|---|---|
| *Voucher* | *Amount* | *Voucher* | *Amount* | *Voucher* | *Amount* |
| 00 | $ 1.65 | 90 | $ 13.69 | 00 | $ 1.65 |
| 01 | 11.87 | 91 | 31.01 | 10 | 5.08 |
| 02 | 11.18 | 92 | 32.08 | 20 | 11.74 |
| 03 | 11.32 | 93 | 27.63 | 30 | 3.65 |
| 04 | 10.16 | 94 | 29.41 | 40 | 13.18 |
| 05 | 4.15 | 95 | 33.68 | 50 | 12.52 |
| 06 | 12.35 | 96 | 31.96 | 60 | 8.95 |
| 07 | 7.89 | 97 | 28.36 | 70 | 11.90 |
| 08 | 12.74 | 98 | 33.41 | 80 | 13.98 |
| 09 | 6.86 | 99 | 28.40 | 90 | 13.69 |
| **Total:** | **$90.17** | | **$289.63** | | **$96.34** |
| **Average:** | **$ 9.02** | | **$ 28.96** | | **$ 9.63** |

*Comments on Exhibit 2:* This exhibit lists three judgment samples of ten items each selected from the universe in Exhibit 1. These three samples were selected on what would seem to be a common-sense basis. The first sample includes the first ten items in the universe; the second sample includes the last ten items in the universe; the third includes every tenth item in the universe.

Comparing the sample estimate of average voucher value with the true average value of $19.95, we see that none of these judgment samples give a good estimate of average voucher value. In this particular case, these results are "rigged" in order to contrast judgment methods with random methods of sample selection. Judgment samples can result in estimates close to the true value. However, the illustration points out the disadvantages inherent in judgment sampling.

jective of survey sampling is to obtain an estimate of some desired characteristic of a population or universe of items. For example, we might sample at various times during a year to obtain an estimate of the average number of vehicles using a particular road. Or we might sample vouchers in order to estimate the number improperly approved for payment. Because estimation of some particular quantity is a frequent concern of management, survey sampling is probably the most commonly used of statistical sampling techniques.

The second of the three techniques falling under the head of statistical sampling is called acceptance sampling. The purpose of acceptance sampling is decision making, typically to decide whether to accept or to reject a particular lot of items. For example, we might take samples from an incoming carload of aggregate to determine whether or not to accept the entire carload. We might sample an outgoing batch of invoices in order to decide whether to accept or to reject the clerical accuracy of the entire batch.

The final statistical sampling technique that should be mentioned is the control chart. Based on the results of a continuous sampling process, the control chart indicates whether or not a process is performing normally, whether or not the process is in control. For example, a control chart based on periodic samples might be utilized to indicate shifts in the quality of a manufacturing process, such as pouring concrete. Similarly, it might be used to indicate a shift in the quality of a clerical process, such as the proper processing of vouchers for payment.

These three techniques—survey sampling, acceptance sampling and the control chart – all fall under what may be called the statistical sampling approach. The statistical sampling approach is itself distinguished from ordinary sampling approaches in the following ways.

*First, statistical sampling involves a particular method of selecting a sample.*

There are many ways in which samples can be selected. Basically, statistical sampling utilizes only one method of sample selection, *random selection.* We will discuss this method of sample selection in more detail later.

*Second, statistical sampling includes a method of measuring sample results.*

After drawing a sample and making an estimate or decision, we are always concerned, or should be concerned at least, with the accuracy of the estimate obtained or the risks attached to the decision made. A great advantage of statistical sampling is that the accuracy of sample estimates and the risks attached to sample-based decisions can be calculated and measured.

*Finally, statistical sampling involves a method of regulating sample accuracy and risks.*

Using statistical sampling techniques, sample sizes can be adjusted to provide any desired level of accuracy for sample estimates or any desired level of risk for sample decisions.

Before turning to some illustrations, I would like to discuss some of these characteristics of statistical sampling in more detail. I will discuss these characteristics in terms of survey sampling—obtaining an estimate—as the most common of sampling techniques.

As we have noted, there are many different methods of sample selection. Most

## EXHIBIT 3

# *Example of a Table of Random Numbers*

| | | | | |
|---|---|---|---|---|
| 15 62 38 72 92 | 03 76 09 30 75 | 77 80 04 24 54 | 67 60 10 79 26 | 21 60 03 48 14 |
| 77 81 15 14 67 | 55 24 22 20 55 | 36 93 67 69 37 | 72 22 43 46 32 | 56 15 75 25 12 |
| 18 87 05 09 96 | 45 14 72 41 46 | 12 67 46 72 02 | 59 06 17 49 12 | 73 28 23 52 48 |
| 08 58 53 63 66 | 13 07 04 48 71 | 39 07 46 96 40 | 20 86 79 11 81 | 74 11 15 23 17 |
| 16 07 79 57 61 | 42 19 68 15 12 | 60 21 59 12 07 | 04 99 88 22 39 | 75 16 69 13 84 |
| 54 13 05 46 17 | 05 51 24 53 57 | 46 51 14 39 17 | 21 39 89 07 35 | 47 87 44 36 62 |
| 95 27 23 17 39 | 80 24 44 48 93 | 75 94 77 09 23 | 48 75 91 69 03 | 55 51 09 74 47 |
| 22 39 44 74 80 | 25 95 28 63 90 | 41 19 48 46 72 | 51 12 97 39 83 | 35 83 23 17 29 |
| 69 95 21 30 11 | 98 81 38 00 53 | 41 40 04 16 78 | 67 29 83 41 18 | 30 90 44 37 64 |
| 75 75 63 97 12 | 11 57 05 86 52 | 82 72 47 72 14 | 37 72 69 75 48 | 72 21 52 51 81 |
| 08 74 79 30 80 | 70 11 66 79 25 | 88 01 94 52 31 | 38 57 98 71 62 | 12 56 61 01 54 |
| 04 88 45 98 60 | 90 92 74 77 87 | 40 18 65 87 37 | 08 68 62 39 52 | 84 74 00 68 18 |
| 97 35 74 05 75 | 42 13 49 48 38 | 74 19 06 42 60 | 20 79 90 81 77 | 18 51 71 27 27 |
| 53 09 93 28 29 | 80 19 68 30 45 | 94 49 49 71 21 | 93 93 71 30 34 | 52 65 83 40 13 |
| 26 36 68 48 09 | 37 69 26 22 80 | 23 34 10 45 70 | 83 51 07 37 44 | 62 96 74 42 64 |

*Comments on Exhibit 3:* This exhibit presents a partial page from a standard random number table of many pages. As we have previously indicated, these random numbers were themselves generated by a random method, in this case, drawings from a lottery.

To use the random number table in the present illustration, we pick any point on the page to begin. Following any systematic pattern, we proceed through the table picking two digit random numbers. We include in the sample those vouchers corresponding to the random numbers indicated. For example, if we started at the upper left hand corner and proceeded down the column of two-digit random numbers, we would include vouchers numbered 15, 77, 18, 08, etc., in our random sample.

## EXHIBIT 4

# *Three Random Samples*

| *Random Sample 1* | | *Random Sample 2* | | *Random Sample 3* | |
|---|---|---|---|---|---|
| *Voucher* | *Amount* | *Voucher* | *Amount* | *Voucher* | *Amount* |
| 15 | $ 23.60 | 15 | $ 23.60 | 14 | $ 23.23 |
| 77 | 19.93 | 62 | 18.59 | 12 | 21.90 |
| 18 | 22.06 | 38 | 25.00 | 48 | 18.50 |
| 08 | 12.74 | 72 | 24.62 | 17 | 23.33 |
| 16 | 19.04 | 92 | 32.08 | 84 | 27.20 |
| 54 | 18.36 | 03 | 11.32 | 62 | 18.59 |
| 95 | 33.68 | 76 | 17.94 | 47 | 23.85 |
| 22 | 16.63 | 09 | 6.86 | 29 | 21.54 |
| 69 | 16.76 | 30 | 3.65 | 64 | 18.70 |
| 75 | 19.28 | 75 | 19.28 | 81 | 16.36 |
| **Total** | $202.08 | | $182.94 | | $213.20 |
| **Average** | $ 20.21 | | $ 18.29 | | $ 21.32 |

of these methods can be classified as judgment methods or judgment sampling, where human judgment is the determining factor in determining what items should be included in the sample. For example, in auditing vouchers, we might leave the selection of vouchers to be audited up to the judgment of the auditor on the job. In many instances, this judgment sample approach may result in a "representative" sample. More frequently, however, this type of approach can lead to biased results. If the auditor is lazy, he may try to select a sample of "good" vouchers to shorten his work. If the auditor is over-eager, he may select a sample of "bad" vouchers to prove how bad things are. Neither sample may give an accurate estimate of the "goodness" or "badness" of the universe of vouchers under audit.

As evident from this illustration, human judgment may be of little value in selecting a "representative" sample. There is, however, a method of sample selection, random sample selection, which should always result in the selection of a "representative" sample. Statistical sampling employs this method of sample selection.

Random sample selection or random sampling is defined as a method of sample selection such that every item in the universe being sampled has an equal likelihood of being selected. That is, at the time of drawing an item, every item has an equal chance of being drawn. There are several ways by which this random selection can be performed.

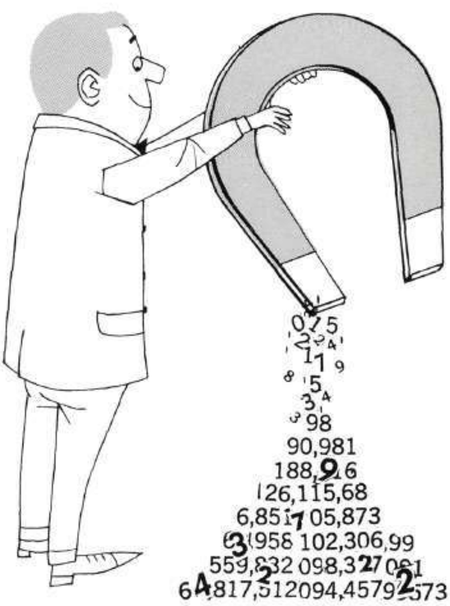
One obvious way of selecting items from a population with equal probability would be to throw dice. In fact, special dice have been constructed for just such a purpose. I have here three such dice. Each of these dice is numbered from 0 to 9 so that if we throw the three dice the chances of any number between 000 and 999 appearing are equal.

Suppose now that we wished to select a random sample from a universe of 1,000 vouchers numbered from 1 to 1,000. One way to select each item in the sample would be to throw the three dice and include the voucher with the same number as that appearing on the dice. Using this method, each voucher would have an equal chance of being included in the sample.

Although throwing dice is one method of selecting a random sample, it is not, in general, a very practical method. What we usually turn to in lieu of dice is a random number table. A random number table is simply defined as a table of the ten digits, zero to nine, which have themselves been selected in a random fashion. Perhaps, the easiest way to think of a random number table is as a listing of the numbers that have appeared when someone took time to throw dice a few thousand times.

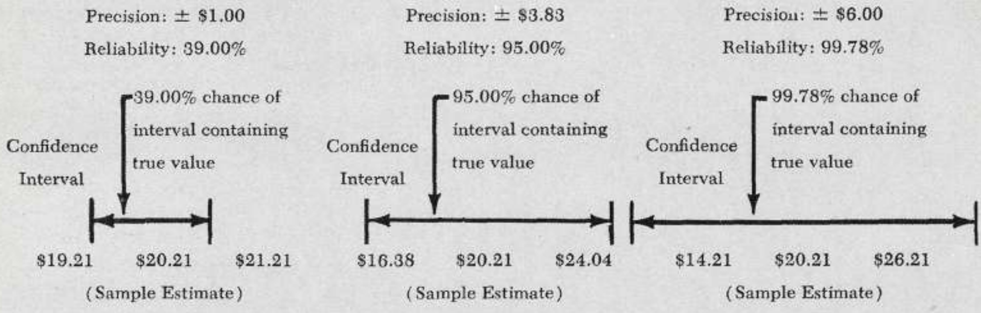
There are a number of random number tables available today which have been constructed by a wide variety of methods — all equivalent to throwing dice. One widely used random number table, for example, was produced by sampling numbers from waybills of the Interstate Commerce Commission. A second set of random numbers has been compiled from numbers drawn in the state lottery in Denmark. A third set of over a million digits was produced by computer.

In selecting a random sample, the numbers in a random number table are used in the same fashion as the numbers appearing on the dice of our previous sample. The item corresponding to a random number in the random table is selected for



## EXHIBIT 5

### *Alternative Expressions of Estimate Accuracy*




*Comments on Exhibit 5:* This exhibit graphically depicts the interrelationship of precision and reliability as a measure of sample accuracy. The exhibit is based on the results of the first random sample listed in the preceeding exhibit.

To repeat the definitions, precision is the plus and minus interval about the sample estimate of $20.31 and may be thought of as a measure of the "closeness" of the sample estimate. Reliability measures the chances that the precision or confidence interval will contain the true value being estimated.

Since the precision and the reliability of a sample estimate are interrelated, the precision and reliability for a particular sample can be alternately expressed in several ways, as this exhibit shows. It should be noted that for a given sample:

1. Reliability increases as precision decreases, or conversely,
2. Precision increases as reliability decreases.

For a constant size sample, it must be emphasized that these alternative ways of expressing sample accuracy are equivalent.

## EXHIBIT 6

### *Effect of Sample Size on Estimate Accuracy*

The following tables illustrate the effect of sample size on the accuracy of estimates.

| *Sample of 10* | | *Sample of 25* | |
|---|---|---|---|
| *Precision* | *Reliability* | *Precision* | *Reliability* |
| ± $1.00 | 39.00% | ± $1.00 | 62.12% |
| ± $3.83 | 95.00% | ± $2.23 | 95.00% |
| ± $6.00 | 99.78% | ± $3.50 | 99.90% |

*Comments on Exhibit 6:* The preceding exhibit illustrated alternative ways of expressing sample accuracy for a sample of constant size. This exhibit presents the effect on sample accuracy – precision and reliability – as sample size is increased. As sample size increases:

1. Reliability increases if precision is held constant,
2. Precision increases if reliability is held constant, or
3. Both precision and reliability increase.

inclusion in the sample. This process is repeated until the sample size to be selected is obtained.

The process of random sample selection always results in more "representative" samples than sample selected on the basis of judgment. This does not mean that a random sample will always give a more accurate estimate of a population characteristic than will any specific judgment sample. However, a random sample is more likely to yield a better estimate. More importantly, the use of random sampling enables measurement of the accuracy of sample results. This measurement of sample accuracy cannot be performed for samples selected on a judgment basis.

This leads to the second statistical sampling characteristic which I would like to discuss in more detail—the fact that statistical sampling affords a method of measuring the accuracy of sample results. On an intuitive basis, each of us has a rough concept of what the accuracy of a sample estimate means. Accuracy involves, in some sense, the notion of how close an estimate is to a true value and a notion as to how much one can rely upon the estimate. In general, this common sense concept of accuracy is much the same as the statistical concept of accuracy. In order to be more precise, however, statisticians define the accuracy of a sample estimate in terms of two concepts which are not familiar to many laymen. These concepts are *precision* and *reliability*.

Using the concepts of precision and reliability, the statistician defines the accuracy of a single sample estimate in the following fashion:

First, the statistician measures off an arbitrary interval about the sample estimate. For example, for a sample estimate of \$100 for the average value of an invoice, the statistician might measure off an interval about the sample from \$95 to \$105, an interval of plus and minus \$5 about the sample estimate. This entire interval from \$95 to \$105 is commonly called a confidence interval. The half width of this interval, in this case, \$5, is commonly referred to as the precision of the sample estimate.

Now it is obvious that the precision of a sample estimate means little or nothing by itself. The statistician can measure off any interval and call it the precision of the sample estimate. What we would like to know for a specific precision or confidence interval is how often, in a series of estimates, this interval will contain the true value being estimated. The chances of the precision interval containing the true value are called the reliability of the sample estimate. For the invoice estimate of \$100 with a precision interval of plus and minus \$5, the reliability might be 39 per cent. Thus, the interrelated statistical concepts of precision *and* reliability together combine to measure the accuracy of a sample estimate.

Now, for a given sample estimate, the accuracy of the sample estimate—the combination of precision and reliability—depends basically upon three factors:

1. *The sampling method used.*
2. *The sample size used.*
3. *The basic variation in the population being sampled.*

Based on these factors, the statistician is able to calculate the accuracy of any sample estimate. Because of the time considerations, I will not discuss in detail the methods and formulas by which precision and reliability are calculated. In general, they are calculated by various mathematical manipulations of the sample data itself.

The final characteristic of statistical sam-

pling which I would like to discuss in more detail is that statistical sampling enables control of sample accuracy. This control of sample accuracy is basically obtained by control of sample size. On a common sense basis, we intuitively expect that a large sample should yield a more accurate estimate than a small sample. The larger sample contains more information with which to work. This intuitive feeling about the effect of sample size on sample accuracy is reflected quantitatively in statistical sampling. As sample size is increased, either the precision of a sample estimate, the reliability of the sample estimate, or both the precision and reliability of the sample estimate are improved.

Some of the statistical sampling characteristics of which we have been talking are illustrated in Exhibits 1-6.

I would like to turn now from the technical aspects of statistical sampling to its practical aspects as applied to problems of accounting and management control. At this point, I believe it is possible to summarize briefly the general advantages which statistical sampling offers as a management control technique.

A first advantage of statistical sampling is that it provides an objective measure of sample accuracy. This is important, in that it provides the user of statistical sampling with a means of measuring performance against a standard for accuracy. In that statistical sampling offers an objective and quantitative measure of sample accuracy, it also forces the user to think more clearly about the standards of accuracy which he wishes to obtain. As accountants, we are all familiar with situations where less than total count accuracy is acceptable and where some form of sampling is currently used. Too often, in such situations, there are no objective standards for the level of accuracy which is being obtained. There is only the feeling, based on experience, that the sampling procedure being used is, in some sense, adequate. In situations such as this, statistical sampling offers the accountant the opportunity to set objective standards—in terms of precision and reliability—for the accuracy desired. To some extent, the use of statistical sampling forces the accountant to do so. And this is very good.

A second major advantage of statistical sampling is that, in many instances, it offers a means of either reducing costs or of increasing the timeliness of information flows. As we have noted total count accuracy is not required, in many, indeed most, accounting situations. Further, as we all know total count results do not always realize 100 per cent accuracy. We all know from our own experience that much financial data is nothing more than estimates. If, by the use of estimates from statistical samples, the volume of data examined can be reduced, then we may have two advantages immediately available. First, the timeliness of information flows can be increased because less data must be examined. Second, the cost of analysis can be reduced.

These advantages of statistical sampling are not solely theoretical advantages. They have been demonstrated in a number of practical applications to actual accounting problems. Brief summaries of a few of these successful applications may serve to illustrate the power of the statistical sampling approach.

While these cases primarily involve business situations, I believe that the principles involved have applicability to many similar situations in government as well.

These illustrations of actual applications of statistical sampling to accounting problems demonstrate fairly, I believe, how statistical techniques can take their place among the kit of accounting tools. Properly used, statistical sampling can provide the accountant with the basis for a more informed judgment and it can give management a clearer evaluation of performance.

I would like to close my remarks this afternoon by noting that the use of statistical sampling techniques in accounting is still a growing and developing process. Although many practical applications of statistical sampling have already been developed, exploration of further uses is still underway. Everything that we have discovered about the applicability of sampling to accounting indicates that the sampling technique has potentialities still untapped. Within the next ten years, I feel certain that the methods of statistical sampling will have found a major role in the day-to-day practice of accounting.

## *Some case studies...*

PHYSICAL INVENTORY

***Objective:*** Sample estimate of year-end dollar inventory value.

***Population:*** Lots of items in physical inventory, 40,000.

***Sampling Unit:*** Unique lot under $500.00 in cost. (Lots costing $500.00 or more and special lots counted 100%.)

***Unit Characteristics Measured:*** Value of lot (cost times quantity).

***Estimate Form:*** Mean per unit. Unrestricted random sampling of lots under $500.00 in cost.

***Estimate Obtained:*** Approximately $4,600,000.00.

***Estimate Precision:*** ± $240,000.00 or ± 5.2%.

***Estimate Reliability:*** 99.73%.

***Sample Size:*** 2,400 lots costing $500.00 or more; 1,400 special lots; 3,620 lots costing under $500.00.

***Remarks:*** Sample results tested for two years with excellent results.

PHYSICAL INVENTORY

***Objective:*** To estimate the percent of metal contained in an inventory of metal-bearing ore.

***Population:*** 22 carloads of ore.

***Sampling Unit:*** Test core of ore.

***Unit Characteristics Measured:*** Percent of metal in test core.

***Estimate Form:*** Two stage mean per unit.

***Estimate Precision:*** 1%.

***Estimate Reliability:*** 95%.

***Sample Size:*** Two cores from each of ten carloads.

***Remarks:*** Sample was also used for "acceptance" purposes.

REVENUE ESTIMATION

***Objective:*** Estimate, for a common carrier, monthly revenue per passenger by routes.

***Population:*** Lifted tickets grouped in trip report envelopes by route; approximately 2,000 envelopes; 500,000 tickets per month.

***Sampling Unit:*** Primary—trip report envelope; ultimate—ticket.

***Unit Characteristics Measured:*** Revenue and passengers per ticket.

***Estimate Form:*** Mean per unit. Stratified two-stage sample: unrestricted random sample of envelopes, systematic sample of tickets in envelopes (routes).

***Estimate Obtained:*** Various: passenger revenue per route.

***Estimate Precision:*** ± 10%.

***Estimate Reliability:*** 95%.

***Sample Size:*** 18,000 tickets.

***Remarks:*** Enabled considerable reduction in sample size.

CONTROL OF INVOICE PAYMENT

***Objective:*** To maintain control over the error rate of incoming invoices approved for payment.

***Population:*** Approximately 11,000 invoices per month.

***Sampling Unit:*** Individual invoice.

***Unit Characteristics Measured:*** If invoice was or was not in error *and* dollar amount of error.

***Sampling Technique:*** Control chart for fraction defective and control chart for dollar error.

***Control Limits:*** Two sigma.

***Sample Size:*** All invoices over $1,000.00 (approximately 3,300). Less than 500 of 7,700 invoices under $1000.00.

***Remarks:*** Offered estimated clerical savings of $25,000.00 per year.

BILLING INSPECTION

***Objective:*** To accept and to reject batches of bills processed for mailing to customers.

***Population:*** Approximately 100,000 bills per month in batches of approximately 300 bills.

***Sampling Unit:*** Individual bill.

***Unit Characteristics Measured:*** If bill was or was not in error.

***Sampling Technique:*** Acceptance sampling.

***Average Outgoing Quality:*** 0.4%.

***Sample Size:*** 70 bills per batch (for average incoming quality of 0.4%).

***Acceptance Number:*** Zero sample bills in error.

***Remarks:*** Plan not used because of tight requirement for average outgoing quality.

SALES TAX ESTIMATION

***Objective:*** Sample estimate of sales tax overpayments for an 826 day period.

***Population:*** Sales tickets for 826 days: 950,000.

***Sampling Unit:*** Day of sales tickets.

***Unit Characteristics Measured:*** Sales subject to tax.

***Estimate Form:*** Ratio estimate.

***Estimate Obtained:*** $28,250.00.

***Estimate Precision:*** ± $4,200.00 or ± 15%.

***Estimate Reliability:*** 95%.

***Sample Size:*** 33 days.

***Remarks:*** Sample results rejected by court as basis for tax claim. 100% count determined overpayment to be $26,750.00.

ACCOUNTS RECEIVABLE AGING

***Objective:*** Sample estimation of accounts receivable dollars and numbers classified as to eight age categories and as to four types of accounts.

***Population:*** 200,000 accounts in 570 trays.

***Sampling Unit:*** Tray of accounts.

***Unit Characteristics Measured:*** Numbers and dollars of accounts receivable classified as to eight age categories and as to four types of accounts.

*Estimate Form:* Ratio estimate. Unrestricted random sampling.

*Estimate Obtained:* \$200,000 for regular accounts in 120-150 day age category.

*Estimate Precision:* $\pm$\$15,000 or $\pm$7.5% for regular accounts in 120-150 day age category.

*Estimate Reliability:* 95%.

*Sample Size:* 45 trays.

*Remarks:* Enabled slight reduction in sample size and measure of accuracy of sample estimates.

## COST INDEX ESTIMATION

*Objective:* Sample estimation of a current year to base year cost index to enable adoption of LIFO inventory valuation.

*Population:* Line items in physical inventory: 10,000–Group A; 12,000–Group B.

*Sampling Unit:* Unique line item.

*Unit Characteristics Measured:* Current year quantities times base year costs; current year quantities times current year costs.

*Estimate Form:* Combined ratio estimate. Stratified sampling with unrestricted random sampling in each of two strata.

*Estimate Obtained:* 1.023.

*Estimate Precision:* $\pm$0.01 or $\pm$1%.

*Estimate Reliability:* 95%.

*Sample Size:* 262 line items.

*Remarks:* Enabled adoption of LIFO inventory valuation with substantial savings.

## CHARACTERISTICS OF PROFITABLE STATISTICAL SAMPLING SITUATIONS

*Statistical sampling is most advantageously employed in situations where:*

1. Basis data characteristics can be measured either in numerical or in yes-no form.
2. Less than 100% accuracy is acceptable in estimates.
3. There is a large volume of relatively homogeneous data.
4. Estimates are required on a recurring basis.

The first two conditions are mandatory for the use of statistical sampling. The last two conditions govern its profitability in use.

H. JUSTIN DAVIDSON directs the national statistical sampling program for the firm. Prior to joining the Pittsburgh Office in 1957, Mr. Davidson was associated with the Operations Evaluation Group (Navy–Massachusetts Institute of Technology) and the Arabian American Oil Company. He received an M.S. degree in mathematical economics from the Carnegie Graduate School of Industrial Administration in 1955. In 1961 he became a CPA in Pennsylvania and is now in our Chicago Office.