



AN INVESTIGATION OF THE APPLICATIONS
OF STATISTICAL METHOD TO THE
AUDITING OF SALES

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**AN INVESTIGATION OF THE APPLICATIONS OF STATISTICAL METHOD
TO THE AUDITING OF SALES**

**By
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INTRODUCTION

For some years auditors have been expressing opinions based on tests of the accounting records. The reliability of their confidence in the tests commonly employed has been seriously opened to question by various authorities and various attempts have been made to develop standards of auditing as guides for the exercise of judgment. This seems to skirt the problem, so this study was designed to develop a method of determining the limits of confidence whereby the auditor's judgment of materiality or immateriality may be attested and by which reasonable standards may result.

The problem was limited to sales because ^{15. 1. 62} ~~the case study~~ involved an aspect of sales, and further, if the method and arguments presented are valid for sales, they may be generalized to other pertinent parts of auditing with the exception of out offs necessitating a testing procedure. //

The more recent researchers have been concerned with the use of sequential sampling developed during the war by the Statistical Research Group at Columbia University. Another area of research not approached in this study concerns itself with an analysis of errors.

The methods of research involved reading all the available material on statistical auditing, reviewing various tests and case studies for the auditing techniques relevant to sales,

searching various statistics texts for clues and finally making the case study. The most intriguing and at times most disheartening problem was the finding of a suitable statistical approach which omitted insignificant refinements of theory, since the auditor requires practical methods without theoretical elaboration. Quinn McNemar's Psychological Statistics was found the most useful in the development of this method.

PRESENT TESTING PROCEDURES IN AUDITING

In any discussion of testing, particularly as it applies to auditing, it would first be best to develop the concept of testing. We may well ask, what does the word testing mean? The dictionary definition of the verb suggests that to test is to prove, try the quality of, or examine. (1) As a noun, the meaning connotes an examination. (2) This definition infers that the testing will be in toto. However, as applied to auditing, the transitive verb testing means to sample or to determine the accuracy by selecting and studying representative items or samples from a given collection or class of transactions or other data. (3) Another auditor, Montgomery, says that test checking is based on the mathematically-founded assumption that an analysis of representative samples of a group of items indicates the quality of the whole. (4) However, no attempt is made by Montgomery to particularize the mathematics to which he refers. These definitions differ with

(1) "A Dictionary of American English" Vol IV, Edited by Sir William A. Craigie and James R. Hulbert, Univ. of Chicago Press, Chicago (1944) P. 2308

(2) "New Standard Dictionary of the English Language" Edited by Isaac K. Funk, Funk & Wagnalls Co., New York (1943) P. 2459

(3) E. L. Kohler, AUDITING AND INTRODUCTION To the Work of the Public Accountant, 1st. ed., Prentice Hall, New York, P. 21 (1947)

(4) Robert H. Montgomery, AUDITING THEORY AND PRACTICE, 6th ed., Ronald Press, New York, P. 36 (1940)

the dictionary meaning as stated above. Another accountant defines testing, the noun, as a limited examination or verification by sampling. This definition is in agreement with the dictionary. (5) The dictionary makes a distinction between testing and sampling. As a verb, sampling means to examine by use of a portion or specimen. The noun, sample, is defined as a part of anything presented as evidence of the quality of the whole. (6) The latter definition corresponds with the use of the word as applied in statistics. A sample is a part of the whole, the entire data, if available, or that is to say, the defined population. (7) Where we can not take the aggregate or whole; we do the next best thing and try to obtain a selection of members, which is called taking a sample. (8) Montgomery states that the basis of test checking may be all items in a specified period, or all items over a certain minimum amount of dollars for a period. As a guide, one may use letters of the alphabet, or percentage of the total either in dollars or amounts. The method of sampling will depend on the

(5) Thomas W. Byrnes, K. L. Baker, O. A. Smith, AUDITING with Practice Problems, 1st. ed., Ronald Press, New York, P. 6 (1948)

(6) "New Standard Dictionary of the English Language"
Op. Cit. P. 2168

(7) Quinn McNemar, PSYCHOLOGICAL STATISTICS, 1st. ed. John Wiley & Sons., Inc. New York P. 46 (1949) and Herbert Arkin, R. C. Colton, AN OUTLINE OF STATISTICAL METHODS 4th ed. rev. Barnes & Noble, Inc. New York P. 113 (1950)

(8) G. Udny Yule, H. G. Kendall, An Introduction to the THEORY OF STATISTICS, 11th ed. Charles Griffin & Co. London, P. 9 (1937)

type of item, volume tested, and the system of internal control. The auditing use of the word "sampling" is not synonymous with the statistical word "sampling" since its theoretical basis includes no probability theory as any statistical method requires.

With the advent of big business, there developed the necessity for making the audit a technique of analysis of selected samplings of accounts rather than an attempt to examine all of the transactions for the period. (9) It has become a custom and, with few exceptions, has proved sufficient. (10) To examine in detail all transactions requires a cost surpassing all reasonable bounds of benefit or safeguards, and places an undue burden on industry. However, the extent of such sampling is left to the individual accountant's judgment. (11) This judgment is based on the client's system of internal control. (12)

Consider, now, what are the typical sampling procedures

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- (9) Walter A. Staub, AUDITING DEVELOPMENTS DURING THE PRESENT CENTURY, 1st. ed. Harvard Univ. Press, Cambridge, Mass. P. 10 (1942)
- (10) EXTENSIONS OF AUDITING PROCEDURE, (Report of May 9, 1939, as modified and approved at the Annual Meeting, September 19, 1939) American Institute of Accountants, New York, P. 3 (Oct. 18, 1939)
- (11) STATEMENTS ON AUDITING PROCEDURE No. 1, Issued by the Committee on Auditing Procedure, American Institute of Accountants, New York, P. 5 (Oct. 1939)
- (12) TENTATIVE STATEMENT OF AUDITING STANDARDS - Their Generally Accepted Significance and Scope, Special report by the Committee on Auditing Procedure, American Institute of Accountants, New York, P. 25 (1947)

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that this is crucial for ensuring transparency and accountability in the organization's operations.

2. The second part of the document outlines the various methods and tools used to collect and analyze data. It highlights the need for a systematic approach to data collection and the importance of using reliable sources of information.

3. The third part of the document describes the process of identifying and measuring the key performance indicators (KPIs) that are most relevant to the organization's goals. It stresses the importance of selecting KPIs that are both measurable and meaningful.

4. The fourth part of the document discusses the importance of regularly reviewing and updating the data collection and analysis process. It notes that the organization's needs and goals may change over time, and therefore, the data collection process must be flexible and adaptable.

5. The fifth part of the document describes the various ways in which the data collected can be used to inform decision-making and improve the organization's performance. It highlights the importance of sharing the data with relevant stakeholders and using it to identify areas for improvement.

6. The sixth part of the document discusses the importance of ensuring the accuracy and reliability of the data collected. It notes that this requires a high level of attention to detail and a commitment to using only the most reliable sources of information.

7. The seventh part of the document describes the various ways in which the data collected can be used to monitor and evaluate the organization's progress towards its goals. It highlights the importance of using the data to identify trends and patterns that can help the organization make informed decisions.

8. The eighth part of the document discusses the importance of ensuring that the data collection and analysis process is transparent and accountable. It notes that this requires a high level of communication and collaboration between all stakeholders involved in the process.

9. The ninth part of the document describes the various ways in which the data collected can be used to improve the organization's overall performance. It highlights the importance of using the data to identify areas for improvement and to implement effective strategies to address these areas.

10. The tenth part of the document discusses the importance of ensuring that the data collection and analysis process is ongoing and continuous. It notes that the organization's needs and goals may change over time, and therefore, the data collection process must be flexible and adaptable.

11. The eleventh part of the document describes the various ways in which the data collected can be used to inform decision-making and improve the organization's performance. It highlights the importance of sharing the data with relevant stakeholders and using it to identify areas for improvement.

12. The twelfth part of the document discusses the importance of ensuring the accuracy and reliability of the data collected. It notes that this requires a high level of attention to detail and a commitment to using only the most reliable sources of information.

13. The thirteenth part of the document describes the various ways in which the data collected can be used to monitor and evaluate the organization's progress towards its goals. It highlights the importance of using the data to identify trends and patterns that can help the organization make informed decisions.

14. The fourteenth part of the document discusses the importance of ensuring that the data collection and analysis process is transparent and accountable. It notes that this requires a high level of communication and collaboration between all stakeholders involved in the process.

that are used in auditing generally, and specifically as related to sales, that involve testing yet exclude cut-offs. Without attempting to be exhaustive, representative methods are presented in Table I on the next page.

As the reader may already have concluded after reading Table I that there is great use of the word "test", but little attempt appears to have been made to develop a technique of representative sampling.

The following quotation typifies the auditor's approach to testing: (13)

TEST-CHECKING OR TESTING - This means the complete verification of a portion of accounting transactions. Testing is common in audits to assure the auditor that transactions are in order for the untested portion of the year, after having verified all transactions for a certain limited period of the year, or after having tested transactions at random.

In order to test-check in a reasonable manner, accounting transactions and entries must be classified logically. For example, they may be grouped as follows: sales records footings, purchase record postings, purchase vouchers and invoices, cash receipts and disbursements postings, cost of sales footings and postings, cancelled cheques, pay rolls, balances of accounts receivable, etc. After proper classification of the items, the next step is the determination of the number of items of each classification to be tested;

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The majority of accounting entries are honestly and correctly made; the purpose of the test check is to review supporting evidences in order to detect errors and fraud and in order to be in a position to judge impartially the accuracy of the accounts. The auditor must be satisfied that the transactions are legitimate and that the accounting for them is proper, so that the financial statements are not affected and so that an opinion of the statements may be rendered. No definite rules can be set forth for the amount of test-checking, as this is

(13) Arthur W. Holmes, **AUDITING Principles and Procedure**, 2nd ed. rev., Richard D. Irwin, Chicago P. 101 (1947)

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AN ANALYSIS OF TYPICAL SAMPLING IN THE AUDIT OF SALES

[illegible]

TABLE 1 - Continued

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dependent upon the judgment of the auditor, his experience, the system of internal accounting control in operation, and the conditions existing in each engagement. - - -

Testing may take place for certain selected weeks or months, or it may be at random. Random tests either satisfy the auditor that the classification of items sampled is correct to a high degree of probability or the results of the test are unsatisfactory. If not satisfactory, additional tests must be made.

The reader's attention is again directed to the fact that no theory of probability underlies the auditor's sampling methods. In order for a sample to be random, each item must have an equal chance of selection and each sample must include items from the whole population. To base samples on one day, three days, one month or three months does not qualify as random. It is likely, at this point that the question will form in the reader's mind, what is the statistical theory of sampling?

The object of sampling is to give the maximum information about the population. (14) Obviously these are estimates, therefore the next aim of sampling is to determine the degree of confidence we can put in our estimates. (15) The accuracy of the estimate will depend upon (a) the way in which the estimate is made from the data of the sample and (b) the way in which the sample was obtained. The process of sampling consists of choosing a predetermined number of individuals from the parent universe. This may be done in three ways; random, purposive, or mixture of the two. Randomness exists when each member of

(14) G. Udny Yule, M. G. Kendall, Op. Cit. P 334

(15) Ibid P. 335

the universe has the same chance of being chosen, personal bias must be eliminated. A method or code must be used which leaves nothing to the observer's idiosyncracies. (16) Such a method may be developed by use of Tippetts numbers. Purposive sampling is to select the average in each group. The practical use of random sampling lies largely in the fact that it allows us to measure objectively, in terms of probability, errors of estimation or the significance of a result obtained from a random sample. The purposive methods have not as yet been able to do so. (17) Usually as the random sample becomes larger, it becomes more representative, whereas owing to bias, the purposive sampling in general does not. Further, the object of the sample is to tell us about the parent population, purposive sampling may tell us more about the mean, but will not tell us about the extremes. (18)

Thus it can be seen that the auditors are constantly introducing bias into their samples which no known methods can express scientifically with any degree of confidence. True enough, the auditor is sampling but his methods involve purposive sampling. Montgomery has taken a step in the right direction but seems to void his point by reference to the "auditors" sampling methods. (19) For, as pointed out above, purposive sampling is

(16) Ibid P. 339

(17) Ibid P. 345

(18) Ibid P. 347

(19) R. L. Montgomery Op. Cit. P. 36

not random.

The limitations of the present methods of auditing make it impossible to substantiate objectively the auditor's judgment. This becomes an important point if the auditor should be forced to appear as an expert witness or as a defendant in a court room. The question may well be put to him what objective measures of confidence does the auditor possess to prove his right to an expression of an opinion, namely, the unqualified certificate. Traditional methods will leave the auditor at the mercy of the court because his measures normally are subjective, yet there are objective measures available which will relieve the auditor from such embarrassment.

The auditor who samples two months of transactions (16 2/3%) and finds few errors concludes that the client's system is working and that he has a right to rely upon it. There are several points overlooked in this illustration of typical field work. The first point overlooked is that the auditor's sample is not random. By picking two time periods as pointed out previously under the definition of sampling, the auditor is not in a position to draw a mathematically (logical) conclusion with any limit of confidence. The second viewpoint disregarded, is that few auditors ever actually relate the total errors found in dollars with the total sampled of a particular phase of the audit or accounting procedure such as sales. Each error is compared with the auditor's concept of materiality and not the sum of the errors in dollars. One

reason is that his emphasis is placed on individual entries and not the total of the sample.

Granstoun has summarized the point well by saying: . . .

textbooks point out that the extent to which sampling procedures are applied will vary under different conditions and that decision as to their extent must be a matter of the auditor's judgment. While that is unquestionably true, the fact remains that no standards have been set; the auditor therefore has no help in forming his judgment, and there are no consistent measures by which the reasonableness of his judgment can be attested. (20)

This authority further points out the need for standard percentages or quantities that make up the sample. In other words, he is attempting to arrive at standard sample sizes in order that the sample may be adequate, that cost of the audit may not be excessive, and that the auditor may prove his work before client or jury.

The purpose, then of this paper, is to develop a method of determining limits of confidence in the auditing of sales whereby the auditor's judgment of materiality or immateriality may be attested and by which reasonable standards may result.

(20) William D. Granstoun, "A New Look at Basic Auditing Techniques", The Journal of Accountancy Vol. 86:4 P. 274-283 (Oct. 1948)

$$\begin{array}{cccc} & & & \cdot \\ \bullet & \bullet & \bullet & \cdot \\ & & & \cdot \end{array}$$

1. *Journal of the American Medical Association*, 1997; 277: 1033-1038.

REVIEW OF LITERATURE ON STATISTICAL AUDITING

The first article appearing in print on the subject of statistical auditing was that of Lewis Carman published in the American Accountant, Dec. 1933.(21) Carman was concerned with the probability of discovering fraudulent entries in a large group of entries. The idea was based on the assumption that the uncovering of a false item is the signal to stop and reconsider the sampling process. For example, let us examine (on the next page) one of the tables (Table 2) Carman used.

Suppose there were 20 false items, then the most economical sample is 15% and the possibility of uncovering one of the false items is 19 out of 20 times used or 95% confidence. However, this does not go further than the uncovering of one false item. The auditor is confronted with the necessity of continuing the sampling or extending the scope of his sampling.

The next article written was by Robert H. Prytherch. (22) He points out that Carman must assume the number of false entries. This, however, is not known. So Prytherch proceeds to give an approach based on the following example involving the testing of purchases to compute a reasonable assumption.

(21) Lewis A. Carman, "The Efficacy of Tests" THE AMERICAN ACCOUNTANT, Vol. XVIII (Dec. 1933) P. 360-366

(22) Robert H. Prytherch, "How Much Test Checking is Enough?" THE JOURNAL OF ACCOUNTANCY, Vol. 74 No. 6 (Dec. 1942) P. 525-530

TABLE 2

PROBABILITY OF ENCOUNTERING AT LEAST ONE FALSE ITEM*

Assumed Number of False Items in Groups		Most Economical Random Sample (approx.)	Probability of Encount- ering at Least One False Item (approx.)
Over	40	8%	over 95%
"	40	10%	" 95%
"	20	15%	" 95%
"	15	20%	" 95%
"	10	22%	" 90%
"	9	24%	" 90%
"	8	26%	" 90%
"	7	28%	" 90%
"	6	30%	" 85%
"	5	35%	" 85%
"	4	40%	" 85%
"	3	45%	" 85%
"	2	50%	" 75%

* Lewis A. Carman "The Efficacy of Tests", The American Accountant Vol. XVIII (Dec. 1933) P. 362



Total purchases	\$50,000
Number of entries	400
Average dollar amount	\$ 200
5% of total possible false entries	4,000
Average number of false entries	20

Referring to Table 2, it would require 15% of 400 entries of that 60 entries be examined. The probability would be 19-1 of uncovering at least one false entry. Should a false item be found, it is then necessary to extend the audit to find other false items.

This sampling, however, does not mean one or two months transactions, but that the samples be chosen on a random basis of every 5th or 6th item until a total of 15% is obtained or some other method satisfactory for the basis of random selection. (23)

The reasoning behind this is that if the errors are concentrated in six months, say 12 of them, the probability of uncovering a single one by examining two months completely (16 2/3%) is 77%, but if the errors are concentrated in one month, the probability of uncovering any one of them is 16 2/3%. (24) Thus, one can see the tremendous risk the auditor is taking under existing practices. Yet note that although the concept was developed first in 1933 then expanded

(23) Ibid P. 525

(24) Ibid P. 528

in 1942, eight years later, no change has yet been made in typical methods. See Table 1

In 1947 Leo Herbert and also Jerome Abrams came out in the New York CPA with articles on sampling. (25) (26) The article by Herbert reiterated the three classical rules for sampling: the sample must be representative, adequate and stable. By representative is meant that the sample must be chosen at random in order for the theory of probability to be operative. Adequacy has reference to avoiding small samples. However, this seems to ignore the whole body of theory involving small samples. Stability means that any increase in the sample size develops no significant change in findings.

Abrams brings out an interesting point that Garman and Prytherch based their findings on the normal distribution, but he feels that the errors more nearly approximate the Poissonian distribution which is a greatly skewed curve. However, he does not follow up his supposition which this study will do.

Reopening of the subject literarily was initiated by John Neter in May 1949. He discussed the application of sequential sampling to auditing which this study will develop with

(25) Leo Herbert, "Practical Sampling for Auditors", THE NEW YORK CERTIFIED PUBLIC ACCOUNTANT, (Jan. 1947) Vol. XVII No. 1 P. 58

(26) Jerome Abrams, "Sampling Theory Applied to the Test-Audit" THE NEW YORK CERTIFIED PUBLIC ACCOUNTANT, Vol. XVII, No. 10 (Oct. 1947) P. 645-652

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in financial matters. The text outlines various methods for organizing and storing data, including digital databases and physical filing systems. It also mentions the need for regular audits and reviews to ensure the integrity and accuracy of the information.

2. The second section focuses on the role of communication in achieving organizational goals. It highlights that effective communication is a key factor in building a cohesive team and fostering a positive work environment. The text provides practical advice on how to improve communication skills, such as active listening, clear articulation of ideas, and the use of appropriate communication channels. It also discusses the importance of maintaining open lines of communication between all levels of the organization.

3. The third part of the document addresses the challenges of managing time and resources efficiently. It notes that time is a finite resource, and therefore, it is crucial to prioritize tasks and allocate resources wisely. The text offers strategies for time management, including creating a schedule, setting deadlines, and delegating responsibilities. It also discusses the importance of monitoring and controlling resources to avoid waste and ensure that the organization's objectives are met within the allocated budget.

4. The final section discusses the importance of continuous learning and development. It states that in a rapidly changing world, individuals and organizations must stay up-to-date with the latest trends and technologies. The text encourages a culture of learning, where employees are encouraged to seek out new knowledge and skills. It also mentions the importance of providing training and development opportunities for employees to enhance their performance and contribute to the organization's success.

Lawrence L. Vance, the next writer. (27) Without solving it, Meter raised the practical problem of setting up a criterion upon which errors of transactions can be classified as to their effect in making the transaction as a whole acceptable or unacceptable. In September of 1949, Lawrence L. Vance pointed out that statistical sampling is a tool and the method can be used only upon the basis of some standard population, (a concept which Vance failed to define), with which the actual sample can be compared. (28) He also pointed out: "that the method is appropriate only for those areas of accounts where a relatively large amount of detail work of homogeneous character can be isolated." (29) ^ASince ~~the~~ statistical method will not particularly uncover the isolated error but ^{it} helps the auditor to evaluate the quality of the ^{4.5}client's work, ~~the~~ approach is no advance in uncovering the occasional fraudulent error except that more adequate samples may result in raising the general standard of auditing. |

In 1950 Vance published a book on sequential analysis as

(27) John Meter, "An Investigation of the Usefulness of Statistical Sampling Methods in Auditing", THE JOURNAL OF ACCOUNTANCY, Vol. 87, No. 5 (May 1949) P. 390-398 and also John Meter, "The Application of Statistical Techniques in Auditing Procedures" THE NEW YORK CERTIFIED PUBLIC ACCOUNTANT, Vol. XIX No. 6 (June 1949) P. 345-350

(28) Lawrence L. Vance, "Auditing Uses of Probabilities in Selecting and Interpreting Test Checks", THE JOURNAL OF ACCOUNTANCY Vol. 88, No. 3 (Sept. 1949) P. 214-217

(29) Ibid P. 216

it applied to auditing outlining the technique in detail. (30)

The basis for sequential sampling is the likelihood ratio. It requires the use of two hypothesis, H_1 that the population has P_1 (percentage) defectives or fewer, and H_2 , that is, has P_2 (percentage) defectives or more. If the probability of drawing the sample from H_1 is P_1 and of drawing it from H_2 is P_2 then the likelihood ratio is $\frac{P_2}{P_1}$. The level of risk we accept in making a decision is expressed in two parts. We will designate the risk of accepting H_2 when H_1 is true as (a) or alpha and the risk of accepting H_1 when H_2 is true as (b) or beta and (N) as designating the size of the sample. Vance's table appears as Table 3.

The values tentatively suggested are P_1 (percentage defectives or less) = .005 and P_2 (percentage defectives or more) = .03. The meaning is that 1 error in 200 is acceptable whereas 3 in 100 are not acceptable. (31)

Vance defines errors as consisting of two groups, substantive and procedural errors. Substantive errors include errors in computations, errors in posting, errors in accounting principles and errors in omission. An example of a procedural error would be the failure to put a countersignature

(30) Lawrence L. Vance, SCIENTIFIC METHOD FOR AUDITING, 1st. ed. Univ. of California Press, Berkeley and Los Angeles P. 87 (1950)

(31) Ibid P. 29 Attention is called to the fact that Vance changes his notion on standard population stated on P. 19 of this paper to a standard percentage of error.

TABLE 3

ACTION POINTS FOR SEQUENTIAL TESTS *

(When $\alpha = 0.05$, $b = 0.10$ and p_1 and p_2 have the values shown)

$P_1 = 0.005, P_2 = 0.03$		
n	y_1 (accept)	y_2 (reject)
2	...	2
29	...	2
89	0	3
100	0	3
160	1	4
171	1	4
239	2	5
243	2	5
303	3	6
314	3	6
374	4	7
385	4	7
446	5	8
457	5	8
517	6	9
528	6	9
588	7	10
599	7	10

The symbol (...) means that the next larger sample size should be used unless the number of rejects found is sufficient to reject sample.

* Lawrence L. Vance, SCIENTIFIC METHOD FOR AUDITING
University of California Press, Berkeley and Los
Angeles P. 91 (1950)

upon a check otherwise properly issued. (32) Vance also feels that the definition of error should be as broad as possible since there will be a few errors uncovered. (33)

In applying the method to auditing of sales, Vance points out the original records relating to sales invoices, shipping orders, customer orders, and sales journal are proper areas for the statistical method. (34)

One of Vance's cases is given in Appendix A in detail merely to acquaint the reader with his approach.

[Where it is desired to raise the representation of the sampling, stratification may be used. This method is available where the data may be classed in mutually exclusive strata. With reference to auditing, the strata may be based either on the amounts in the transaction or the amounts in the calculations. The procedure requires that proportions of the population falling into each category be known and that samples taken from each category be related in size by the same proportions. (35)]

There is an attempt by auditors to stratify the data for ordinary auditing. For example, in examining the extensions of inventory, material items may be examined completely while small items may be only scanned.

(32) Ibid P. 30

(33) Ibid P. 32

(34) Ibid P. 44

(35) Ibid P. 72

As the reader by now can appreciate, there is quite a difference between the sampling done by statisticians and that done by auditors. The auditors have a tendency to examine the material items and neglect the small ones. There is no quarrel relative to examining the significant ones but the smaller ones must be included in at least a proportion of a minimum sample. Sales records are almost invariably sampled for periods of a week or more. The result is a biased sample with its inherent difficulties of mathematical precision. Since at present, the auditor's samples are so frequently biased and difficult to defend, the only conclusion that is tenable is that by the use of random sampling the auditor may defend his methods which is indeed a great advance if no other end was served. (36)

Wm. D. Cranstoun in 1948 listed three limitations of present statistical auditing as he views the subject;

1. No probability ratio can be calculated for a combination consisting of two or more procedures.
2. The statistical approach is directed only to calculating chances of discovering a single false item, when actually the auditor is concerned with their extent and size.
3. Since probability is based on the number of items, no distinction is drawn as to the importance of items. (37)

Excluding the types of audits designed to uncover fraud only,

(36) Ibid P. 77

(37) William D. Cranstoun, "A New Look at Basic Auditing Techniques" THE JOURNAL OF ACCOUNTANCY Vol. 86, No. 4 (Oct. 1948) P. 274-283

this investigation will solve questions 2 and 3 and suggest an answer for 1 above. For this purpose an actual case was designed and a method developed which will be described later and discussed in the conclusions.

STATISTICAL METHODOLOGY

The problem of the auditor is one of uncovering errors either of omission, commission, or of principle. The auditor examines the transaction sampled for existence or absence of error. No attempt is made to classify the errors as bad, very bad and terrible. The only classification is in terms of dollars and more precisely, in terms of whether the error is material or immaterial. The concept of materiality is a subjective determination by the auditor based upon the relevant factors. The error itself, although measured in dollars is an error in recording, posting, calculation or of principle which alone is not subject to classification. (38)

The study of the existence or non-existence of a characteristic, error, in the data is referred to by statisticians as a study of attributes. As the result of a sample, those items possessing the attribute are placed in one class while those not possessing the attribute are placed in a separate class. The classes are mutually exclusive. The first class is designated as (p) and the second class is (q). The relation of $1 - p = q$ exists between the classes. It is advisable to reduce the frequencies of the classes to percentages. (39)

(38) Lawrence L. Vance, SCIENTIFIC METHOD FOR AUDITING 1st. ed. Univ. of Calif. Press, Berkeley and Los Angeles, P. 12 (1950)

(39) Quinn McNemar, PSYCHOLOGICAL STATISTICS, 1st. ed. John Wiley & Sons, Inc. New York P. 62 (1949)

Suppose it is determined by random sampling that 5% of 200 invoices were improperly extended or that 10% of 100 sales invoices were improperly priced. The mathematical model, the binomial theorem, permits one to generalize from these statistics the amount of the error. We are faced then with the problem of making an inference from the sample value to the population value, i.e., from (p) to (P) where (p) stands for the observed percentage possessing the characteristic studied (errors in extension or errors in pricing) and (P) stands for the percentage in the defined population that show the characteristic. If we were to take successive samples of size (n) and make a distribution of the observed percentages, the distribution would center about (P) with a spread or standard deviation equal to the square root of $P(100 - P) / n$. Since we do not know (P), we must use the observed percentage as a basis for determining its standard deviation. The standard deviation of a binomial distribution of a percentage will be given approximately by $\sigma_p = \sqrt{\frac{pq}{N}}$ in which:

p = observed percentage or attribute expressed as a decimal

q = 100 - p

n = the number of cases studied in the sample

If 10 invoices out of 200 chosen at random from a year's sales invoices possessed errors in multiplying quantity times price it may be inferred that the (P) population percentage of such errors is likely to be between the limits $(p \pm 3\sigma_p)$ or $5 \pm 3 (1.54)$ i.e. .38% and 9.62% approximately. By using

a three sigma (3 σ) confidence limit it may be said that in 99.7 samples out of 100 samples the population percentage (P) will lie between .38% and 9.62% approximately.

One limitation to the use of the above method is namely: that each individual member of the universe must be replaced before the next sample is drawn. This means that each event has the same chance of success. (40)

Another condition for this method is that the success of different events, the existence or non-existence of error, are independent in that the result of one event is not affected by the results in prior events. (41)

The assumption underlying this formula is that the observed (p) will be a very close approximation of the population (P). The smaller the standard deviation is the closer the approximation becomes. (42)

McNemar states that the relative form is unworkable when (p) is small. (43) Yule and Kendall, however, point out that the formula $\sigma_p = \sqrt{\frac{pq}{n}}$ is the relative form of $\sigma = \sqrt{npq}$ and the same results will be obtained by both formulas. (44) ^{It is} They further point out by the use of the latter formula, that

(40) G. Udny Yule, M. G. Kendall, An Introduction to the THEORY OF STATISTICS, 11th ed. Charles Griffin & Co. London, P. 350 & 357-8 (1937)

(41) Ibid P. 350

(42) Ibid P. 354, 355

(43) Quinn McNemar Op Cit P. 62

if (p) is small, so that p^2 as compared with (p) may be neglected; then $pq = p(1-p) = p - p^2 =$ approximately p , and consequently we have approximately; $\sigma = \sqrt{np} = \sqrt{m}$.

That is to say, if the proportion of failure be small, the standard deviation of the number of failures is the square root of the mean number of failures and hence the standard deviation can be determined even if (p) is unknown except that it is small. (45) Thus it would appear that the limitation of McNemar is unjustifiable particularly when (n) is large.

In auditing, the (n) will usually be large so that this limitation will be of no practical significance to the practicing accountant.

The experimental unit used in this study is the pricing of a part. The part to be priced was chosen on the basis of every fifth item in the strata. Since the characteristics of the data are not determinable other than by detailed examination and further, the parts were chosen throughout the temporal period, the sample then may be considered random because the bias of the investigator was eliminated. The limitation involving the replacement is not a factor because no order of parts existed and success of selection of a part depended upon whether the investigator began counting to five with the first part found in that strata or successive items. For randomness, the investigator based the beginning number of each sample upon

(44) G. Udny Yule, Op Cit P. 353

(45) Ibid P. 356

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a random number table using 2,3,1 for the 20% (approximately) samples and splitting the 20% samples in half for six 10% (approximately) samples. The three 20% samples were added together to give one 60% sample including some overlap.

The independence of each event was not prejudiced by the results of prior events by virtue of the sampling technique.

The study introduced a variant in the method of stating (p) (q) and (n). Although the experimental unit was concerned with the act of pricing, the successes or failures by themselves are not the primary concern of the auditor because he is concerned with materiality and not the number of errors. Therefore, it seemed quite logical to measure the factors in terms of dollars. The errors in dollars divided by the total dollar value of the sample is used as (p).

For example, in sample one, five errors in 105 items were found. Using the standard deviation formula for a percent

$$\sigma_p = \sqrt{\frac{pq}{n}}$$

the resulting standard deviation is

2.7% or a three sigma variation of 8.1% adding this to (p) of 4.7% the limits range from 0 to 12.8%. This appears to misstate the facts. Referring to Table 7, with a sample of

\$2201.32, only \$4 of errors were found assuming $\frac{4}{2201.32} = (p)$, which is .18% or very near perfect. The upper limit is .45%.

To the common sense of the average auditor, the method involving dollars seems more meaningful and more usable in the exercise of judgment.

The limits of .003 variation of a percent of a sample with

a large (n) and a (p) may be expressed by the formula $P \pm 3 \sqrt{\frac{PQ}{n}}$

Varying values of this are available in tables, excerpts from one of which may be found in Appendix B. Referring to Appendix B, suppose in the audit of \$10,000 of sales invoices from a total of a \$1,000,000 sales, 0.6% total errors were found. Following in the upper control limit the line marked 0.6% to the column marked 10,000 is the figure 0.83%; in the lower control limit the corresponding figure is 0.37%. The interpretation is that the variations due to sampling are from 0.83 to 0.37 of one per cent. Thus, based on a 3 σ confidence limit, this sample could not have arisen from a population containing more than 0.83 of one per cent of errors or less than 0.37 of one per cent errors in 99.7 chances out of 100. By using dollar values for (n) this means that based on the results of the sample there will be between \$3700 and \$8300 of total errors, in the population, but no more, in 99.7 times out of 100 samples.

The principle of stratification is to break up non-homogeneous data into more homogeneous groups. Within each group random selection is employed. The size of each group in the sample should be proportionate to the relative importance of the stratum to the total of all the strata. Where the differences between strata are pronounced, a more accurate sample results. (46) Dollar values lend themselves easily to strati-

(46) Frederick O. Mills, STATISTICAL METHODS Applied to Economics and Business 2nd ed. rev. Henry Holt & Co., New York P. 462 (1938)

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fication. They are mutually exclusive, that is to say, \$2.50 does not appear in a class interval of five to ten dollars.

McNemar introduces a correction of the standard deviation formula for stratification namely $\sigma_p = \sqrt{\frac{pq}{n} - \frac{\sigma_p^2}{n}}$. However, in this study the (r 's) are so small that the correction becomes theoretical and has no significant bearing upon our results. However, should (p) be much larger, say 30%, then it may be well to use the correction. (47)

Vance uses a method of weighting stratified results for which no authority could be found to support him and thus his technique is excluded from use in this study. (48)

(47) Quin McNemar Op Cit P. 334

(48) Lawrence L. Vance Op Cit P. 73

A CASE STUDY OF AN ASPECT OF STATISTICAL AUDITING OF SALES

Vance pointed out that it would be desirable to summarize results in terms of the money value of errors in the population, but this did not seem to be a very practical objective. (49) Accounting errors arise almost entirely from human fallibility and there is no regular or simple pattern of human fallibilities on which probability calculations could be based.

This, the investigation set out to prove. The idea was to use indirect argument that the results would be consistent with the thinking of Vance. If they were inconsistent, or in other words, a pattern adaptable to statistical study and as accurate and as sensitive as his results were found, then his position is erroneously taken.

A fairly large manufacturer agreed to a limited examination of a small segment of his sales. The system of internal control existing is as follows: A parts order is written up and the customer's credit is approved. With approval, a factory move order is made in triplicate. The first copy is used as an acknowledgement copy, the third as a packing slip and the second follows the parts from the warehouse to shipping department and thence to the inventory control where it is priced, extended, and posted to inventory records. From the second copy

(49) Lawrence L. Vance, **SCIENTIFIC METHOD FOR AUDITING**, 1st ed. Univ. of Calif. Press, Berkeley and Los Angeles, P. 12 (1950)

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of the extended move order, the billings are made, proofed, and the extensions are checked by a comptometer operator. Four copies of the billings are made: One to the treasurer's department, second to the accounting department with the third and fourth going to the customer. From the second the receivables are posted, the order is listed, and a sales distribution is made.

Based upon the accounting system a list of possible errors was developed:

1. The credit may not be approved. This was considered under control because of matching the treasurer's copy with the customer's statement.
2. The incorrect part number may have been recorded on the move order, the incorrect item shipped or improper posting to the inventory. Since shipments were impossible to check and management did not desire that the service department personnel be involved in the investigation, these items were not included in the study, even though no checks or balances to the knowledge of the accounting department existed with reference to these possible errors.
3. Another type of error which was not controlled was the pricing of the parts. This could be reviewed without involving the service department and further this was the item interested in by management.

4. The billing errors due to proofing and comptometer operations did not seem too fruitful for study.
5. Since the year end closings were in progress and the public accountants were present, the accounting department felt that a study of the recording errors in accounts receivable, sales distribution and costing were not practicable at this time.

Therefore, the study involved items looked up in the pricing book. The experimental error was defined as the correctness or incorrectness of the price looked up and recorded as the unit price times quantity. (50) The error occurred in the act of pricing and was measured in dollars.

The first procedure was to tabulate the sales of these particular parts for the year. It was found that there were 526 items to be looked up and the sum of unit prices times quantity for the year totaled \$7055.82.

The second procedure was to develop a scheme of stratification which at best was unwieldy, but 12 strata were made as shown in Table 4 on the next page.

It will be observed from the stratification and distribution that the curve is highly skewed similar to the Poisson distribution. It was then decided to take two sets of

(50) From here on the figures are slightly disguised, but with no effect on the results.

TABLE 4

SUMMARY OF STRATIFICATION OF SALES TEST DATA

For the Year Ended Dec. 31, 1950

Class no.	Class Mid-point (in dollars)	Experiment- al Units	% of experi- mental Units	Amount of class (in dollars)
1	\$.50	147	27.95	\$ 61.15
2	1.50	68	12.92	99.02
3	2.50	36	6.85	87.12
4	3.50	36	6.85	122.58
5	4.50	23	4.37	101.53
6	5.50	25	4.76	133.98
7	8.50	60	11.40	490.89
8	15.00	70	13.30	1018.44
9	35.00	45	8.56	1522.41
10	125.00	10	1.90	905.25
11	300.00	4	.76	1117.45
12	700.00	<u>2</u>	<u>.38</u>	<u>1396.00</u>
Totals		526	100.00	\$ 7055.82

samples based upon the above stratification. The first set consisted of three samples approximately 20% each of the experimental units based on taking every 5th item, except the first sample, in each stratification where possible. However, in those strata, insufficiently large, successive samples were not included. The item chosen was priced and extended. Any difference was noted as an error. A feature complicating this process was that a price revision had been inaugurated after the price book was published. Every part was first determined if it was included in the revised listing, if not, the part was found in the main body of the catalog and then compared with the price on the invoice. If the price on the invoice varied from the revision if listed there, or the catalog if not, an error was recorded. The unit price times the quantity was then extended to get the total error. No attempt was made to segregate the errors dependent upon their increase or decrease of gross sales. It was felt that this was not a factor in the study. The three 20% samples added to give one 60% sample with some overlap which is included in the table.

The second set consisted of 6 samples approximating 10% each of the experimental units using the same procedure as outlined above.

The results of the sampling are shown in Tables 5 and 6. Included in the samples discussed above, the first sample of 20% of the population was taken in groups of five scattered through the stratum. At least one item was used from each

TABLE 5

SUMMARY OF THREE 20% SAMPLES AND TOTAL OF THE THREE SAMPLES

For the Year Ended Dec. 31, 1950

<u>Class</u>	<u>Errors (in dollars)</u>				<u>Errors (in units)</u>	
	<u>1st Sample</u>	<u>2nd Sample</u>	<u>3rd Sample</u>	<u>Total 60% Sample</u>	<u>1st Sample</u>	<u>Total</u>
1	\$.10	\$.13	\$.20	\$.43	2	4
2	.05	.05	.00	.10	1	2
3	1.15	.15	1.45	2.75	1	3
4	00	00	00	00	0	0
5	00	00	00	00	0	0
6	00	00	00	00	0	0
7	2.70	.65	00	3.35	1	2
8	00	00	00	00	0	0
9	00	00	00	00	0	0
10	00	00	00	00	0	0
11	00	00	00	00	0	0
12	<u>00</u>	<u>00</u>	<u>00</u>	<u>00</u>	<u>0</u>	<u>0</u>
Total	<u>\$ 4.00</u>	<u>\$.98</u>	<u>\$ 1.65</u>	<u>\$ 6.63</u>	<u>5</u>	<u>11</u>

TABLE 6

SUMMARY OF SIX 10% SAMPLES

For the Year Ended Dec. 31, 1950

<u>Class</u>	<u>Errors (in dollars)</u>					
	<u>A Sample</u>	<u>B Sample</u>	<u>C Sample</u>	<u>D Sample</u>	<u>E Sample</u>	<u>F Sample</u>
1	\$ 0	\$.10	\$.13	\$ 0	\$.20	\$ 0
2	0	.05	0	.05	0	0
3	0	1.15	.15	0	0	1.45
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	2.70	.65	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Totals	<u>\$ 0</u>	<u>\$ 4.00</u>	<u>.93</u>	<u>.05</u>	<u>.20</u>	<u>1.45</u>

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stratum. This was taken to compare the results of sequential analysis with the method developed in this study.

Based upon the sequential sampling of Vance, the first sample would have been rejected since five errors are more than the three errors allowed by the Table Vance uses for samples of approximately one hundred. (51) In order for this sample to have been accepted, no errors should have been found. Rejection is predicated upon the finding of three or more errors. Yet by the methods of this investigation, the sample would have been accepted as demonstrated below. Even from a total of 60%, with some overlap, the sample would have been rejected based on sequential analysis as eleven errors were found, yet only \$6.63 of errors were actually found.

It was concluded, after much cogitation, that since the errors and (p) percentages were low the standard of comparison should be high. Thus a 99% confidence was set for this experiment. However, the confidence limit could easily have been set before the experiment or the audit engagement as well. The confidence percentage will vary only for areas of work and not necessarily from company to company. This overcomes a tremendous obstacle inherent in standard sample sizes which would of necessity vary from concern to concern and then not prove conclusive because of poor results necessitating additional sampling. The method of this study eliminates such difficulties and in addition places the emphasis on the major factor, namely, the degree

(51) See Table 3

of confidence that may be expressed.

The following Table 7 gives the upper and lower limits for the various stratified samples based on dollar errors. Additional tables will be found in the Appendix C, D, and E giving more detailed information on the results shown in Table 7. It should be noted that in the large samples, the upper limits are still less than 1%. If we should desire to be within 1% of accuracy, these samples show the work to be well within our standard.

If further proof is needed, the null hypothesis theory could be used, for say, the first sample. (52)

Where $n = 2201.32$ (the dollars)

Standard = $P' = .01$

Actual (p) = $.0018$

Standard Error = $\sqrt{\frac{.01 \times .99}{2201.32}} = .002$

Difference between actual and standard = $.0082$

$$\frac{.0082}{.002} = 4.10$$

From which it could be concluded that $.0018$ could not be $.01$. In order for the study to be incorrect, the results must be less than one.

Referring to Table 7, these values for upper and lower limits may be found in published tables, a part of which is included in Appendix B. Comparing this table with the results of this study, the first sample is within $.0002$ of being $.002$.

(52) Quinn McNemar, PSYCHOLOGICAL STATISTICS, 1st. ed.
John Wiley & Sons, Inc. New York, P. 63 (1949)

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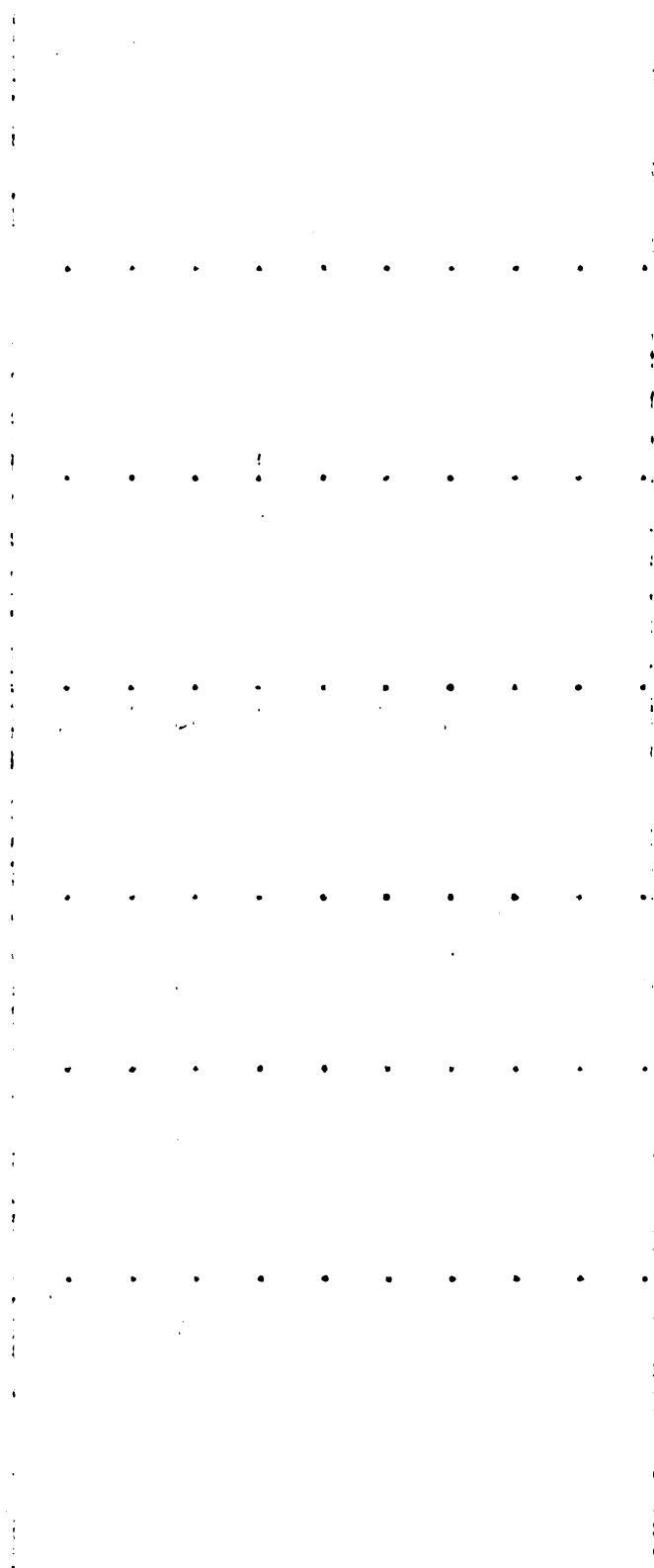
(52) Quinn McNemar, *PSYCHOLOGICAL STATISTICS*, 1st. ed.
John Wiley & Sons, Inc. New York, P. 63 (1949)

TABLE 7

SUMMARY OF RESULTS - UPPER AND LOWER LIMITS

Sample	Amount (n) (dollars)	Errors (dollars)	Percent of error (p)	Sigma	Three Sigma	Upper limit in %	Lower limit
Total	\$4497.76	\$ 6.63	.147 %	.00057	.00171	.318%	0
1	2201.32	4.00	.18	.0009	.0027	.45	0
2	1356.36	.98	.072	.00073	.00231	.303	0
3	940.08	1.65	.176	.0014	.0042	.596	0
A	1369.93	.00	.000	.0000	.0000	.000	0
B	836.39	4.00	.48	.0024	.0072	1.2*	0
C	640.33	.93	.145	.0015	.0045	.595	0
D	715.47	.05	.007	.00031	.00093	.1	0
E	540.48	.20	.037	.00077	.00231	.268	0
F	339.62	1.45	.427	.0031	.0093	1.357*	0

* With a standard of one percent, these results are not within our standard



Using the sample size as dollars (2201.32) and using the .2% column the figure .0050 is found under sample size 2000 and .0044 is found under sample size 3000. Since the 2201.32 is the correct value, it would lie between .0050 and .0044, and also, since the percentage is .0002 less than .002 and the value for .1% is between .0031 and .0027 the figure of the study of .0045 is very close.

This, then, is what Abrams would have found, no doubt, had he developed his hypothesis. (53)

Thus a simple procedure has been developed whereby the accountant by relating his errors found in dollars to a percentage and using an (n) of the total dollars of the sample may find a factor which will give him the information necessary to express or disclaim the client's work. Note that with a 1% standard only, samples B and F would have been rejected which may be the chance fluctuation noted above or more likely it may be that 10% or less (in dollars) is too small a sample. Assume for purposes of explanation that they are correct, attention is called to the fact that the percentage of errors is less than one half of one percent yet they are not within our standards. In fact, the possible error is approximately three times the error uncovered. Thus, just because the auditor finds less than 1% error is not necessarily sufficient evidence to conclude that the possible error is less than 1%. This method

(53) Jerome Abrams, "Sampling Theory Applied to the Test-Audit", The New York Certified Public Accountant Vol. XVII No. 10 P. 645-652 (Oct. 1947)

then gives the auditor an objective measure of his reliability based upon the facts he uncovers in the audit. What embarrassment the auditor might experience in thinking that errors totaling \$5000 of a million dollar sales ($\frac{1}{2}$ of 1%) is all the error whereas actually it may be \$15,000. Particularly does this become significant when the standard is lower, such as 95% or 90% allowing 5 or 10% error. As these errors are tripled, a judge or jury may well ask what evidence did the auditor possess to formulate his opinion or what confidence can the auditor justify.

The question arises why does this highly skewed curve (Poisson or Bernoullian) work for auditors. This study would indicate that errors are normally low in the average well run business with an adequate system of internal control. In addition, this study showed that few errors are made on large items but occasional errors are made on small items. See Tables 5 and 6.

No errors were found in the classes representing 90% of the total dollar value. Since therefore, the errors discovered in this study were small, the distribution of the errors is a highly skewed curve. This finding completely refutes Vance's contention that no pattern exists. (54)

Although the method of this study is limited to errors measurable in dollars, it has been proved as sensitive or more sensitive than the sequential sampling method. Therefore, the

statement by Vance noted above is inconsistent with the finding of this study and a measure of materiality for the purposes of auditing has been developed.

CONCLUSION

In conclusion, it would appear that Montgomery's definition of testing in the auditing sense is more nearly correct but that his bases for testing are not in agreement with his definition but should include in all his bases for representative samples the words "randomly selected. " (55)

The first limitation relating to two or more procedures cited by Cranstoun on page 21 is generally valid as of today. This study overcame such difficulty by defining the experimental unit in terms of a specific job related to the validity of original evidence of sales invoices. Yet this study gives no evidence that the definition of error could not be expanded.

His second limitation regarding false entries seems too narrow. Sequential sampling and the technique of this study have broadened the scope of statistical auditing much more than merely fraud detection. In fact, these methods are the least advisable for fraud which, however, does not impair their usefulness since fraud detection today is not the most important reason for an audit, ranking eighth in a list of 12 reasons for certified statements as given by Holmes. (56)

(55) Robert H. Montgomery, AUDITING THEORY AND PRACTICE, 6th ed., Ronald Press, New York, P. 36 (1940)

(56) Arthur W. Holmes, AUDITING Principles and Procedure, 2nd ed. rev. Richard D. Irwin, Chicago, P. 3 (1947)

The third limitation concerning materiality cited by Cranstoun is valid for the sequential type of analysis but it is invalid with reference to the method of this study. The reason is that dollars (a common denominator) and not the error itself can measure materiality as well as immateriality. Therefore, a distinction is drawn because an error of \$500 in a sample of a \$1000 is 50% which changes the (p) in the formula of this investigation. Although in sequential analysis it is only one error. Thus the method presented in this paper gives the auditor a procedure whereby his judgment of materiality or immateriality can be attested.

Rather than determining standard sample sizes as Cranstoun has suggested, it would seem more logical to set standard precision estimates (probabilities). (57) That is to say, does the auditor wish to be correct within 1%? For in the final analysis the auditor is interested in the confidence that he may express in his report. To follow standard sample sizes seems to place the accent on the wrong syllable. Thus, the method used in this study results in standards which have more universal application than sample sizes. It is more significant to the profession to set a standard of 99% confidence for sales regardless of the size of the business than to work out sample sizes for varying size businesses.

Another allegation this study refutes is the notion of

(57) See P. 7 of this paper

Vance's that a standard population is necessary. (58) The method of this study does not require a standard population since such criteria are unnecessary in studying attributes as mentioned in the chapter on statistical method.

Finally, although this paper has limited its discussion to the auditing of sales, the method is applicable to many areas of auditing such as vouchers, accounts receivable, inventory and postings. Thus, wherever testing is used to determine the reliance upon the system of internal control, other than cut offs, the method of this study may be seriously considered as the vehicle of accomplishment.

(58) See P. 17 of this study.

APPENDIX A

A CASE STUDY USING SEQUENTIAL ANALYSIS IN AUDITING*

The material of this case is the raw material and merchandise inventory of a small manufacturer of surgical appliances. The inventory consisted of 1,060 items, and the clerical work is the area tested. Extensive examination of this inventory in the actual audit, plus thorough scrutiny by the senior partner of the firm (who did not participate in its preparation) revealed only 5 errors. The examination of the clerical work was not complete, although 100 per cent of footings and 25 per cent of extensions were checked by the auditors. We may assume, however, that all errors were found for the purpose of trying statistical techniques. Upon such an assumption, three independent random samples were drawn. In the first two samples no errors were found in the first 89 items drawn, so that the population would have been accepted with a minimum sample if we use the values of Table 10* (left section) as a basis for judgment. In the third sample an error was found when item 45 was drawn; this indicates an indeterminate result. A continuation of the drawing was made and after 160 items were included no other error had been found, so the population would have been accepted in the third case also without as much effort as was expended by the auditors in practice. In the event the reader is concerned about our failure to run down the 5 errors in this inventory, it should be observed at this point that where any error is considered likely to be very important and its discovery essential, the sampling method is not appropriate, whether applied scientifically or not. Such an attitude requires complete examination of the area involved.

*Lawrence L. Vance, SCIENTIFIC METHOD FOR AUDITING
University of California Press, Berkeley and Los
Angeles P. 51, (1950)

APPENDIX B

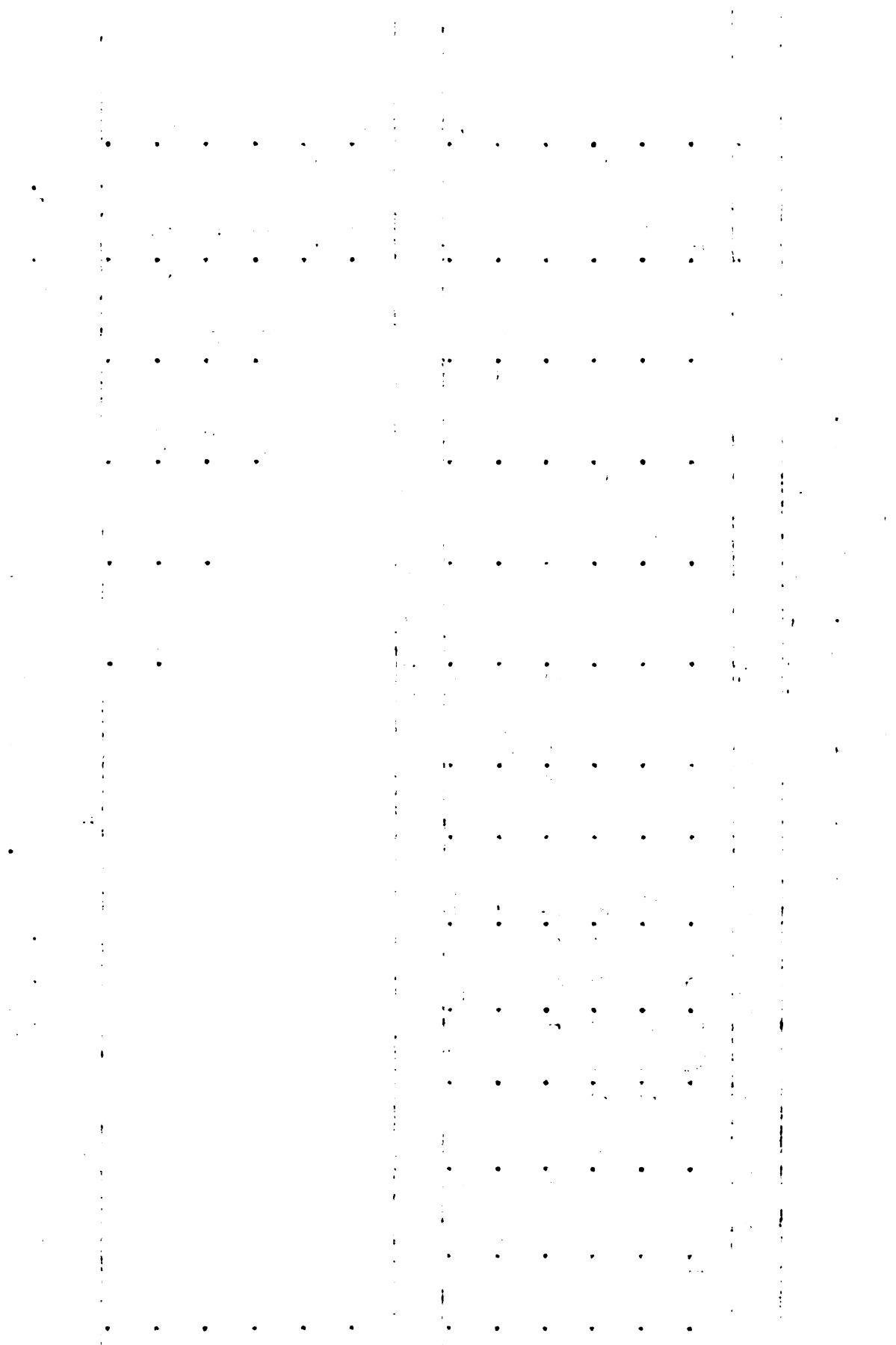
TABLE OF 3 SIGMA CONFIDENCE LIMITS FOR BINOMIAL DISTRIBUTION IN PER CENT*

For Sample Sizes 100 to 50,000 and p of .1% to 1%

Upper Control Limit - Group Size													
%	100	150	200	300	400	500	800	1500	2000	3000	5000	10,000	50,000
0.1	1.05	0.87	0.77	0.65	0.57	0.52	0.44	0.34	0.31	0.27	0.23	0.19	0.14
0.2	1.54	1.29	1.15	0.97	0.87	0.80	0.67	0.55	0.50	0.44	0.39	0.33	0.26
0.4	2.29	1.95	1.74	1.49	1.34	1.25	1.01	0.89	0.82	0.75	0.67	0.59	0.48
0.6	2.92	2.49	2.24	1.94	1.76	1.64	1.42	1.20	1.12	1.02	0.93	0.83	0.70
0.8	3.47	2.98	2.69	2.34	2.14	2.00	1.75	1.49	1.40	1.29	1.18	1.07	0.92
1.0	4.00	3.44	3.11	2.72	2.49	2.33	2.06	1.77	1.67	1.55	1.42	1.30	1.13
Lower Control Limit - Group Size													
0.1											0.01	0.06	
0.2											0.07	0.14	
0.4										0.05	0.13	0.21	0.32
0.6									0.08	0.18	0.27	0.37	0.50
0.8								0.11	0.21	0.31	0.42	0.53	0.68
1.0								0.23	0.33	0.45	0.58	0.70	0.87
(The blank spaces indicate zero)													

(The blank spaces indicate zero)

* Herbert Arkin, R. R. Colton TABLES FOR STATISTICIANS Barnes & Noble, Inc.
New York Excerpts from P. 134 and 135 (1950)



APPENDIX C

SUMMARY OF THE COMPUTATION OF (p)

Sample	Amount (in dollars)	Errors (in dollars)	Amount divided by errors (in percentage)
I	\$ 4497.76	\$6.63	.147%
1	2201.32	4.00	.18
2	1356.36	.98	.072
3	940.08	1.65	.176
A	1396.93	0	0
B	836.39	4.00	.48
C	640.33	.93	.145
D	715.47	.05	.007
E	540.48	.20	.037
F	339.62	1.45	.427

TABLE 1		
Summary of the results of the analysis of the data from the 1970-71 season		
Area	Number of plots	Number of plots with a significant difference in yield
1. North of the main road	10	10
2. Between the main road and the main road	10	10
3. Between the main road and the main road	10	10
4. Between the main road and the main road	10	10
5. Between the main road and the main road	10	10
6. Between the main road and the main road	10	10
7. Between the main road and the main road	10	10
8. Between the main road and the main road	10	10
9. Between the main road and the main road	10	10
10. Between the main road and the main road	10	10

APPENDIX D

SUMMARY OF COMPUTATION OF UPPER AND LOWER LIMIT FOR 20%
SAMPLES AND TOTAL OF THE THREE SAMPLES

<u>Sample</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>	<u>Sample I</u>
The decimal of sample errors to sample (p)	.0018	.00072	.00176	.00147
The reciprocal (q)	.9982	.99928	.99824	.99853
Sigma (σ)	.0009	.00073	.0014	.00057
Three sigma (3 σ)	.0027	.00231	.0042	.00171
Upper Limit (p + 3 σ)	.0045	.00303	.00596	.00318
Lower Limit (p - 3 σ)	.0000	.00000	.00000	.00000

1. $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

2. $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

•	$\frac{1}{2}$	•	$\frac{1}{2}$	•	$\frac{1}{2}$	•	$\frac{1}{2}$
•		•		•		•	
•		•	$\frac{1}{2}$	•	$\frac{1}{2}$	•	
•		•		•	$\frac{1}{2}$	•	$\frac{1}{2}$
•		•	$\frac{1}{2}$	•		•	$\frac{1}{2}$
•	$\frac{1}{2}$	•		•		•	$\frac{1}{2}$

APPENDIX E

SUMMARY OF COMPUTATION OF UPPER AND LOWER LIMIT

FOR 10% SAMPLES

	<u>Sample A</u>	<u>Sample B</u>	<u>Sample C</u>	<u>Sample D</u>	<u>Sample E</u>	<u>Sample F</u>
The decimal of sample errors to sample (p)	0	.0048	.00145	.00007	.00037	.00427
The reciprocal (q)	0	.9952	.99855	.99993	.99963	.99573
Sigma (σ)	0	.0024	.0015	.00031	.00077	.0031
Three Sigma (3σ)	0	.0072	.0045	.00093	.00231	.0093
Upper Limit ($p + 3\sigma$)	0	.012	.00595	.001	.00268	.01357
Lower Limit ($p - 3\sigma$)	0	.000	.00000	.00000	.00000	.00000

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