CO CE & TECHNOLOGY:

A Methodology for the Selection of Interactive Computer Services

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U.S. DEPARTMENT OF COMMERCE
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COMPUTER SCIENCE & TECHNOLOGY:

A Methodology for the Selection of Interactive Computer Services

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A Methodology for the
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ABSTRACT

This publication addresses the comparison and selection of remote access interactive computer services. The comparison methodology presented relies principally on the statistical analysis of measurement data obtained from the interaction between a computer service and a user. One of the most important properties of the methodology is that it incorporates confidence statements about the probability of having made a correct selection. Experimental data are presented to illustrate an application of the methodology, and serve as a basis for a discussion of the cost and appropriateness of using the methodology in various procurement efforts.

Key words: comparison of computers; computer measurement; computer selection; computer services; ranking and selection; selection methodology.

1.0 INTRODUCTION

The comparison of services delivered by a computer to a terminal user is a frequent, important and essential effort for those involved in selecting from among alternative computer services. This is especially true for large industrial and government installations engaged in procurement efforts which may involve millions of dollars [FIP57, TSP77]. The comparison and selection process is a complicated one, based on various criteria. Some of the criteria are measurable (such as system response time), and some are not (such as ease of system use and coherence of system documentation). For those criteria which are measurable, comparison requires collecting and analyzing relevant performance measurements for the various computer services under consideration, in order

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to choose the best one. A simple rule that analysts have used in the past for choosing the best service is the same one that a sound statistical methodology would dictate: pick the service that yields the best measurements, on the average. However, if test conditions are such that the measurement error is relatively large compared to the difference between the services being compared, then the chance of selecting the best service by comparing measurement data is no better than the chance of picking it by random drawing [YOU59].

The comparison of computer services, therefore, requires a methodology designed to lead to the selection of the best computer service, and to provide control of the probability of having made a correct choice. Methodologies dictated by classical statistical designs (which are inappropriate for computer service selection) lead to regression analyses of the data, employing either analysis of variance or curve-fitting techniques [DAV63]. The questions that can be answered using such methodologies are of the type "Is the performance of several alternative systems the same, i.e. are the distributions of performance measurements identical from a statistical point of view?" or "How does one particular system performance parameter depend upon the other system parameters?". In most computer comparison efforts, however, these questions are not appropriate. The question of real interest is: "Which computer service is the best?" or "How do the services rank from best to worst?". It is for problems of this type that statistical ranking and selection procedures were developed [GIB77]. These procedures are applied in the selection methodology described below.

1.1 A Computer Selection Model

A model of the computer service selection process is presented in Figure 1. This model will be used to specify those phases of the selection process which this publication addresses. The model is not intended to represent the entire procurement process. Readers are referred to FIP42 and JOS77 for a broader view of the competitive procurement environment.

Figure 1 shows three phases of the selection process that lead progressively from the set of all computer services under consideration to the isolation of the best one. Each phase involves evaluation of the services with respect to different classes of performance criteria. At each phase, those services

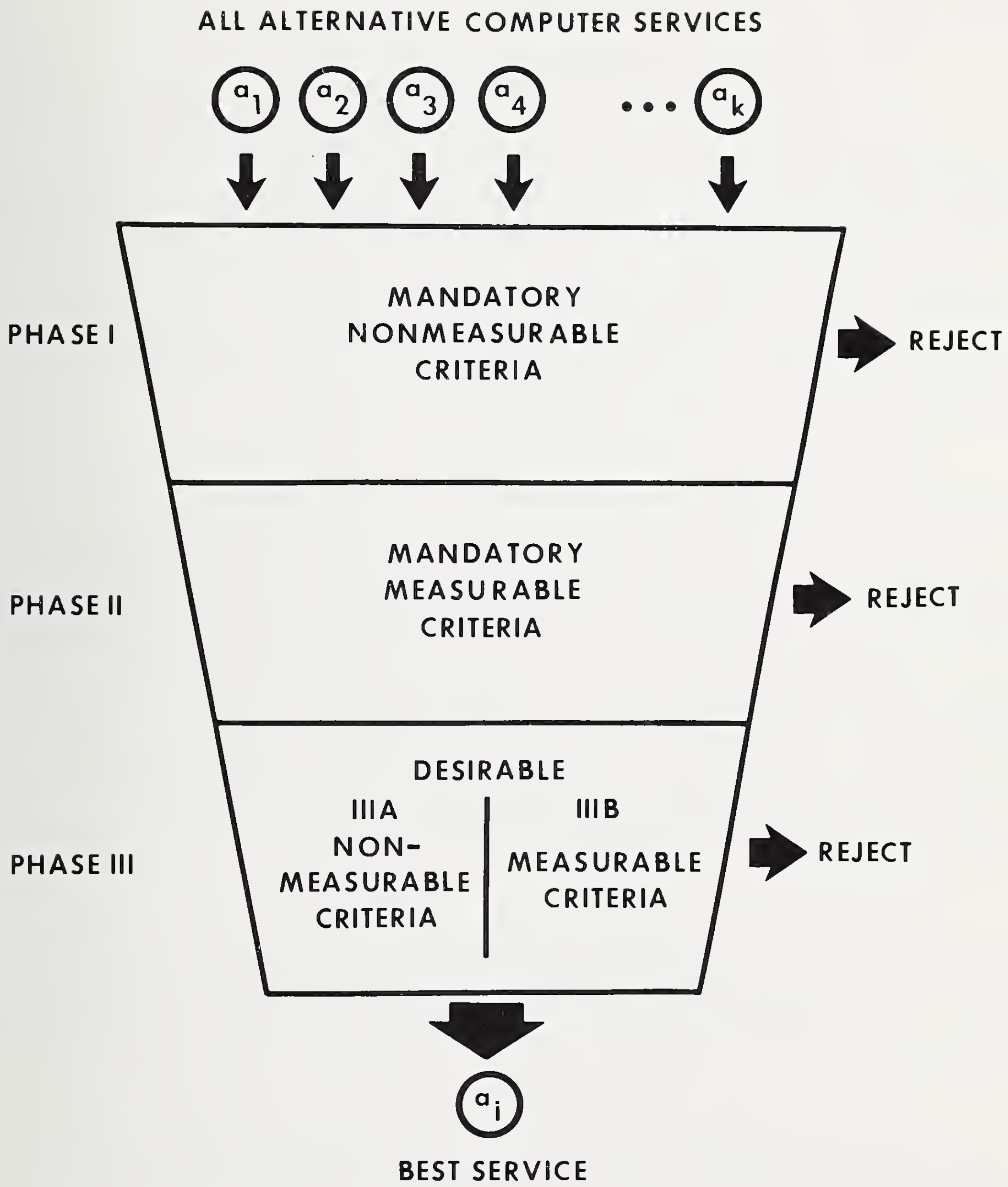

Figure 1. Computer Selection Model [AME78a]

which fail to satisfy the respective performance criteria are eliminated. The kinds of performance criteria that are evaluated are described briefly in Section 1.2. Those phases of the selection process for which the statistical methodology presented here are applicable are then specified in Section 1.3.

1.2 Classification Of Performance Criteria

In choosing the best computer service from several alternative computer services, performance criteria must be defined which describe what is meant by best. These criteria can be divided into those for which no empirical measurement is necessary and those whose values are derived from actual system measurements. For example, evaluating system documentation and amount of main memory does not require measurement collecting activity, whereas evaluating system turnaround time and response time clearly requires measurement.

Performance criteria can be further divided into those which are mandatory and those which are desirable. A mandatory criterion is defined to be any performance requirement which must be satisfied by the computer services being considered for selection. Desirable criteria, on the other hand, are those which are not absolute requirements for system acceptance, but which would make the implementation of the purchaser's work easier. Therefore, if a given computer service does not include some desirable features, it would continue to be considered for selection, but the lack of each desirable feature would perhaps invoke some penalty on the respective computer service [JOS77].

Based on the two characteristics described above, performance criteria can be classified as: Mandatory Nonmeasurable (MN), Mandatory Measurable (MM), Desirable Nonmeasurable (DN), and Desirable Measurable (DM). Examples of each class of criteria are provided in Table 1.

Clearly, there are a large number of performance criteria which may be used as a basis for computer comparison. (See ABR77b, FER78, and GRU75 for examples.) Ultimately the decision about how many and which performance factors are most important in an evaluation is a policy issue. One user may view system reliability as the over-riding consideration in a system selection effort while another might view cost and response time for short edit commands as the most important factors. Usually some combination of various

Table 1

Examples of Performance Criteria

Type	Example
Mandatory Nonmeasurable	1. The system must be fully delivered and operational no later than September 1, 1979.
	2. Timesharing service must include FORTRAN, Basic, Lisp, SNOBOL and editing facilities.
Mandatory Measurable	1. The mean-time-to-failure for a specific one month period must be greater than 4 hours.
	2. 95% of all trivial command response times must be less than 1 second.
Desirable Nonmeasurable	1. It is desirable that the system include Pascal and COBOL facilities.
	2. It is desired that the system provide a text editing capability.
Desirable Measurable	1. It is desired that the system provide a mean turnaround time for the benchmark run of 5 minutes or less.
	2. It is desired that 95% of all trivial command response times be 0.5 seconds or less.

measures of system response time and system costs is used in the selection process.

1.3 Application Of Performance Criteria

Figure 1 illustrates a sequence in which the classes of performance criteria should be applied in the process of choosing the best computer service. This sequence is composed of three phases. Phase I involves the application of MN criteria. The phase is easily managed since each computer service either does or does not have the required characteristic. All of those systems which do not satisfy the MN criteria are eliminated.

Phase II involves the application of MM criteria. In general for each MM criterion, performance measurements are gathered from every computer service and a decision is made as to whether or not the criterion is satisfied. Failure to satisfy a single MM criterion results in a service's elimination.

Finally, determination of the best alternative is made in phase III. This phase is separated into two parts, phase IIIA for the application of DN criteria and phase IIIB for the application of DM criteria. (Note: It is not implied that DN and DM criteria can necessarily be applied separately or in any particular order.) The information required in phase IIIB is similar to the information required in phase II in that it can only be obtained by system measurement. Data is collected from each alternative computer service being evaluated and compared. On the basis of relative performance, one system is selected as the best.

In both phases II and IIIB, comparison requires collecting and analyzing relevant performance measurements for the various computer service alternatives under consideration: in phase II, to select those satisfying certain mandatory performance requirements, and in phase IIIB, to select the best remaining one. It is for these two phases that the selection methodology presented in this publication is applicable.

It should be noted that the selection methodology presented here is capable of specifying the best system only with respect to a one performance criterion at a time. For example, it will guarantee, with a certain maximum probability of error, selection of the best system with respect to script turnaround time, or selection of the best system with respect to response time for short edit commands, and so on. The task of integrating the information provided by the methodology is left to the analyst. Typically, a simple policy which defines the overall best computer service as that one which ranks best with respect to the greatest number of single criteria is satisfactory [LEE77]. A weighted function of several criteria could also be used for final selection, if the function was based on information regarding which computer service was the best with respect to each criterion, rather than on a relative ranking of the computer services from best to worst.

The main components of the selection methodology are:

1. determination of performance criteria which will form the basis of a service comparison,

2. development of a user scenario that is representative of a projected workload,

3. translation of a scenario into individual scripts executable on the respective systems under test, and

4. collection and analysis of the data required for a comparison.

The remainder of this publication is devoted to discussing each component in turn. The main emphasis is on discussion of the fourth component, for which procedures are presented based on statistical ranking and selection theory. The details of executing each step of the comparison methodology is clarified by reference to an actual case study of computer service selection. An important consideration throughout the execution and discussion of the case study is the cost incurred in computer service selection.

2.0 THE COMPARISON METHODOLOGY

Typically, a comparison case study to select a computer service consists of running an identical set of tasks (scripts) on all systems under test during specified periods of the day, and collecting performance and cost measurements during script execution. Scripts, discussed in more detail below, may be driven and the performance measurements made under human or automatic control (see RTE76 for a discussion of automatic script drivers and ABR77a, ROS76, WAT76 for a discussion of an automatic measurement machine). The computer services are then evaluated based on the measurement results and the best one is selected.

Performance and cost data are usually collected in an uncontrolled environment. That is, a user exercises no control over the software, hardware or workload of a computer service during the test periods. This mode of testing is in accord with the actual mode of utilization of a computer service once it has been selected. Users do not have, nor do they desire, such control when they purchase computer services (in contrast to computer systems). However, they do demand a guaranteed level of service at their terminal interface and that is precisely what is measured.

2.1 Comparison Criteria

There are a large number of measures which may be used to describe the demands and needs of a user at an interactive terminal. Abrams and Treu [ABR77b] have tabulated more than fifty of these measures, describing the time, length, rate and ratios of user-computer interactive behavior. Three measures are likely to be of primary interest in an evaluation and selection of computer services: response time, turnaround time and cost.

The importance of response time is generally acknowledged. A preferred definition of response time is the elapsed time from the last user keystroke (which terminates a service request) until the first meaningful system character is displayed at a user's terminal [FIP57]. Response times for various individual commands, and for various classes of commands are useful for service comparison. Individual commands of interest include compile and load-and-execute requests. Classes of commands include short editor commands, status inquiry commands, and database queries.

Interactive turnaround time is measured as the elapsed time required to complete a given sequence of tasks in an interactive mode. As compared to response time, turnaround time requires fewer measurements over a longer interval. In general, these measurements are less expensive to obtain. This advantage, however, is offset by the increased number of tests required to obtain the necessary number of data points [FIP57].

Sporadicity problems, system verbosity, and complexity of the command structures or syntax of a computer service are all reflected in a turnaround time measure. Two services which yield similar response time measurements for a given scenario may yield dissimilar turnaround times for that same scenario.

The cost of a computer service, if not the primary selection criterion, is usually high on a list of important considerations upon which a selection is based. The costs incurred for computer services are typically incorporated into a charging algorithm that is based on the various resources used during an interactive session, such as CPU time, connect time, and so on.

2.2 A User Scenario

A "scenario" is a functional description of an interactive benchmark which is to be run and measured on each service being compared [WAT77]. There are three major workload types which describe remote access interactive computing requirements. They are 1) interactive program development including use of compilers, editors, etc., 2) transaction processing, and 3) remote job entry [CON76]. A scenario being developed for a computer service comparison study may or may not contain elements representing all three types of computing depending on a comparison study's objectives. The number and kind of interactions of each type which are included depend both upon the representativeness which is desired and upon the statistical methodology for the comparison study.

2.2.1 Developing A Representative Scenario -

The degree to which a scenario is required to represent an actual projected workload is a critical issue in an evaluation and selection process. Normally, a scenario is required to closely reflect the functional requirements of a real workload. The identification and quantification of significant real workload characteristics, and the generation of a scenario based on these characteristics, is a major undertaking which has been reported upon elsewhere in the literature [CRO74, NOL74, WRI76] and will not be discussed here.

2.2.2 Constraints On Scenario Development -

The statistical ranking and selection procedures used in the data analysis phase of the methodology described in this publication, which are described in more detail below, typically require 1) that a relatively large number of measurements (about one hundred) be made for each comparison criterion and 2) that the measurements be independent (data independence is a statistical concept which deals with how consecutive data points are related). These two requirements, described below, introduce constraints on scenario development.

Since a large number of measurements may be required, and for some comparison measures like turnaround time, only one measurement can be made per scenario run, the scenario should be relatively short. On the other hand, a representativeness requirement may dictate a relatively long scenario. Thus a balance must be reached by an analyst between including all types of interactive transactions which are representative of a real workload, and keeping the total scenario length to a manageable size. The scenario length directly affects both the cost of a comparison study and the total time required to conduct a study. If only a few runs per day are possible, a comparison study could easily extend over several months.

The requirement that the data be statistically independent poses a problem that must be given careful consideration. If the data are not independent, they are "correlated". This means that the value of a current measurement is affected by the value of a previous measurement. In a comparison study, correlation among data points would be large if consecutive measurements for a given measure were of constantly increasing or decreasing value. This would happen, for example, if there was an unstable environment in which a system had just recovered from a crash, and users were logging on and initiating work in quick succession. Under such circumstances, consecutive response time measurements of the time to log on are very likely be constantly increasing.

Appendix A contains an extensive discussion of the statistical notion of correlation and how it relates to the realities present in computer system data collection. In general, if data are correlated, the number of measurements needed for a given probability of making a correct selection increases dramatically, thus further constraining the scenario length. There are many techniques, however, for avoiding correlation in the data, and often these can be used easily without violating experimental objectives. Thus, with careful planning (and reasonably well-behaved computer systems), a correlation problem can be avoided.

2.3 Script Generation

A machine-independent scenario must be translated into a machine-dependent benchmark called a script for each system under study. This process involves translating general scenario commands into commands that are compatible with each particular system, and possibly modifying small sections of programs which are not directly transportable across heterogeneous computer systems. Care must be exercised to ensure that the scripts which are executed on different systems are as similar as possible.

Typically, the translation must be done in close cooperation with vendor personnel who have a detailed knowledge of the respective computer service. Producing a workable script may require interfacing with system I/O devices, editors, compilers, linkers and loaders, database management systems, and so on.

2.4 Data Collection And Analysis

In any study involving measurement of computer services, the efficiency of the data collection process and the validity of the data analysis depend upon the choice of an appropriate statistical methodology. Ranking and selection procedures (see GIB77 or KLE75 for a survey of these techniques) provide an appropriate foundation for computer service comparison and selection methodology. These procedures can be roughly characterized as following three lines of development: ranking computer services 1) by comparing sample means, 2) by comparing sample percentiles, and 3) by comparing sample proportions. In all three cases, the procedures specify the number of data points which must be collected from each service in a comparison study in order to guarantee that the probability of a correct selection be greater than or equal to a predetermined minimum value. A detailed description of how the three classes of ranking and selection procedures can be applied to computer comparison studies has been described in two recently published papers [AME78b, MAM77]. The main points of these two papers are summarized below.

The use of a mean, percentile or proportion statistic for computer service comparison is an analyst choice based on considerations about the objectives of a comparison study, the statistical properties of the data and the statistical requirements of the selection methodology. (The reader unfamiliar with the statistical terms employed in this report is referred to NAT63.) Means are often used for comparisons when criteria like script turnaround time or script cost are of interest. For comparison criteria such as response time, which tend to have exponential-like distributions [FUC70, TOT65], the mean is not as meaningful a statistic. Percentiles or proportions are more appropriate [AND71, BRO75].

A percentile and a proportion approach to performance are very similar in that they both rely on the cumulative distribution of a single performance criterion. The difference lies in whether an analyst prespecifies a desired percentage value or a desired comparison criterion value. In a comparison based on percentiles, a percentage is predetermined. Results are produced of the form:

> "if computer service A has exactly 90% of its response times less than 3 seconds, and computer service B has exactly 90% of its response times less than 3.5 seconds, then A is better than B,"

where "90%" is prespecified by the analyst. In a comparison based on proportions, a criterion threshold is prespecified. Results are produced of the form:

> "if computer service A has exactly 80% of its response times less than 3 seconds, and computer service B has exactly 87% of its response times less than 3 seconds, then B is better than A,"

where "3 seconds" is prespecified by the analyst.

Mean, percentile or proportion statistics can be used in either phase II (evaluation of mandatory measurement criteria) or phase IIIB (evaluation of desirable measurement criteria) of the selection process. The next two sections of this publication present the details of the ranking and selection procedures applicable for selection in phase II (section 2.4.1), and for selection in phase IIIB (section 2.4.2). A basic set of definitions common to ranking and selection methodologies is presented in Table 2 for easy reference. Table 2 should be read in conjunction with the next sections. The notation used is consistent with that used in the statistical ranking and selection literature and will facilitate further reference to that literature.

The actual step-by-step procedures that are presented in this section, combined with the tables in Appendix B, are complete in that they may be applied without reference to other books or articles. No statistical justification for the procedures is presented. The interested reader is referred to AME78a, GIB77 and KLE75 for the appropriate statistical theory. Also, for those readers for whom this is a first exposure to ranking and selection procedures, it is suggested that section 2.4.1 and 2.4.2 be read in parallel with section 3.3.1 and 3.3.2, respectively, where example applications of each procedure are presented. This mode of reading will provide an intuitive feel for the procedures and will place their necessarily abstract and general steps in an environment with which the reader is already familiar.

In the procedures below, assumptions are made such as the analyst wishing to find the "smallest" mean or the "largest" proportion of one or the other performance measure. These assumptions are made to reflect what typically would be desired in a computer service selection process. Procedures do exist for other selection parameters, e.g. the "largest" mean, and the reader should refer to the ranking and selection literature for these procedures.

2.4.1 Selection Of Services Satisfying A Mandatory Requirement: Based on Proportions -

In the case of selecting those computer services which satisfy a mandatory requirement (phase II in Figure 1), a methodology is required which leads to an analysis of the data that answers the question "Which services are at least as good as a minimum requirement?". The motivation for conducting this type of selection is to screen out some of the alternatives which fail to meet certain minimum performance requirements, thereby reducing the overall number of alternatives from which a final selection is to be

Table 2

Summary of Ranking and Selection Terminology

A. Notation Common to All Procedures

k: number of alternative computer services in the study

P*: desired level of confidence in the correctness of the selection results; P* is a probability of correct selection, and is a value chosen by the analyst

n: number of measurements required from each computer service to guarantee P*

B. Notation Common to Selection Based on Means

x(i,j): jth sample measurement from ith computer service, j = 1,2,...,n

$\overline{x1}(i)$: first stage sample mean of the ith computer service

n1: number of measurements to calculate the $\overline{x1}(i)$'s

$\overline{x2}(i)$: second stage sample mean of the ith computer service

n(i): number of measurements to calculate $\overline{x2}(i)$

$\bar{x}(i)$: weighted sample mean of the ith computer service

b: weight used to calculate the weighted sample mean

d*: the minimum difference to be detected between the sample mean of the best computer service and that of the next best service

$s^2(i)$: sample variance of the ith computer service

C. Notation Common to Selection Based on Percentiles

a: a-quantile used to denote the a-th percentile; e.g., a = .9 for the 90th percentile

d*: the minimum difference to be detected between the smallest a-quantile value and all other a-quantile values

q(i): sample a-quantile of the ith computer service

D. Notation Common to selection Based on Proportions

C(thld): criterion threshold value; i.e., mandatory value for a particular performance measure

X(i): number of measurements from the ith computer service which are less than C(thld)

p(min): minimum proportion of measurements which must be less than C(thld)

p(i): proportion of measurements from the ith computer service which are less than C(thld)

$\hat{p}(i)$: estimate of p(i)

made. The ranking and selection literature refers to selection of this type as selection "better than a standard". The ranking and selection techniques which have been developed for selection better than a standard are <u>not appropriate</u> for computer service selection when performance criteria are being compared at their mean or percentile values. The procedures make assumptions about the data that are clearly not justified in computer service selection experiments (such as equal variance for all systems). But, an appropriate procedure does exist when proportions are the basis for selection.

For selection based on proportions, it is assumed that there are k >= 2 computer services from which it is desired to select a subset of minimal size which contains all computer services satisfying a specific performance requirement. The goal of this procedure is to perform the subset selection in a way which guarantees a probability at least P* that all computer services which meet or surpass a specific performance requirement are contained in a selected subset. P* is chosen by the analyst. A joint confidence statement which can be made with confidence P* is that all of the computer services which are rejected do not meet the performance requirement.

A mandatory performance requirement is stated in terms of a measure threshold value, C(thld), and a minimum required proportion, p(min). For example, if a criterion of interest is script turnaround time, then a possible performance requirement might state that at least eighty percent of the script executions must take less than 10 minutes. In this case p(min) = 0.80 and C(thld) = 10 minutes.

The choices of C(thld) and p(min) are based on nonstatistical considerations such as past performance or projected performance needs. Selection is accomplished via collecting measurements from each computer service under study and estimating the true proportion of measurements lying below C(thld). The analyst is then able to choose those computer services which pass this phase of the selection process.

This procedure for selection assumes that measurements are independent and that measurements from the same computer service have a common probability of being less than C(thld). The procedure makes no assumption about their underlying distribution. The procedure is a four step process:

<u>Step 1</u>: Choose appropriate P*, C(thld) and p(min) values according to nonstatistical considerations.

Step 2: Collect n independent measurements from each of the k computer services. The analyst chooses n based on nonstatistical considerations, bearing in mind that as n increases, more accurate estimates of each alternative's proportion will be attained.

Step 3: Let X(i) = number of measurements from service i which are < C(thld). Note that since n, the total number of measurements made, is identical for each computer service, the X(i) values can be used to indicate a ranking of the true proportions.

Step 4: For each service, compare X(i) to a constant M, which is derived from ranking and selection theory. If X(i) >= M, then include the computer service in the selected subset; otherwise eliminate it. M is determined by table lookup based on the parameters k, n, P* and p(min). Extensive values for M are tabulated in AME78a and have been reproduced in Tables 1-19 in Appendix B.

2.4.2 Selection Of The Best Service -

In phase IIIB of the computer service selection process, a methodology is required which leads to an analysis of the data that answers the question "Which service is the best one?". Ranking and selection procedures exist for choosing the best computer service based on performance criteria expressed in terms of mean, percentile or proportion statistics.

2.4.2.1 Selection Based On Means -

The goal of this procedure is to choose as best that computer service which has the smallest mean value of a single performance criterion. It is assumed that there are k >= 2 computer services from which the best one is to be determined based on the mean of a set of performance measurements for each service. Let $\bar{X}(i)$ represent the sample mean from the ith service, i = 1, 2, ..., k. The probability of a correct selection is desired to be at least P* when the true mean of the best service is at least a distance d* away from the true mean of the next best service. For example, it may be desired to select with 95 percent confidence the best service whenever a difference of 0.5 seconds or more exists between its and the next best service's mean response time. In this case P* = 0.95 and d* = 0.5.

The introduction of d* is required by the nature of the statistical theory upon which the procedure is based. However, it is a useful tool for the analyst in that it provides the ability for stating how close two computer services can be before they are considered identical in the analyst's mind. The statistical theory is such that if the best service and any other service(s) are not separated by a distance d*, then the selection of any one of these close services is considered a correct selection of "the best".

This procedure for selection assumes that measurements from each service are independent and are drawn from a distribution that is normal. A normality assumption holds for certain types of performance data, as will be demonstrated in the case study. Because of a normality assumption, it is necessary to perform a preliminary investigation before using this procedure to verify that such an assumption is valid. Statistical tests for normality like the chi-square or Kolmogorov-Smirnov tests are appropriate [BRA68]. An alternative procedure such as one based on percentiles or proportions will be necessary when the data cannot be assumed normal. The procedure is a five step process:

<u>Step 1</u>: Collect an initial sample of n1 independent measurements from each service and calculate the first stage sample means of the k computer services:

$$(1) \quad \overline{x1}(i) = \frac{\sum_{j=1}^{n1} x(i,j)}{n1}$$

and the sample variances:

$$(2) \quad s^2(i) = \sum_{j=1}^{n1} \frac{(x(i,j) - \overline{x1}(i))^2}{n1 - 1}$$

<u>Step 2</u>: Calculate the total sample size n(i), required for service i:

$$(3) \quad n(i) = \max \left[n1 + 1, \left(\frac{s(i)h}{d^*} \right)^2 \right]$$

where h is a constant whose value is dependent on k, and analyst supplied values of P* and d*. Values for h which are likely to be used in a comparison of computer services are given in Table 20 in Appendix B. These values assume an initial sample size of n1 = 30. As n1 decreases, the values of h increase, thus requiring more second stage sampling.

Other values of h have been tabulated by Dudewicz [DUD72, DUD75].

Step 3: Collect n(i) - n1 additional independent measurements from each service i and calculate the second stage sample means:

$$(4) \quad \overline{x2}(i) = \sum_{j=n1+1}^{n(i)} \frac{x(i,j)}{n(i) - n1}$$

Step 4: For each service calculate the weighted average of the first and second stage sample means:

$$(5) \quad \bar{x}(i) = b\,\overline{x1}(i) + (1-b)\,\overline{x2}(i)$$

where the weight b is given by:

$$(6) \quad b = \frac{n1}{n(i)}\left(1 + \left(1 - \frac{n(i)}{n1}\left[1 - \frac{n(i) - n1}{(hs(i)/d^*)^2}\right]\right)^{1/2}\right)$$

Step 5: Select the service with the smallest weighted mean as the best.

2.4.2.2 Selection Based On Percentiles -

A percentile, like the 90th percentile, may also be referred to as an alpha-quantile (denoted a-quantile), e.g. the .9-quantile for the 90th percentile. The a-quantile terminology is consistent with the ranking and selection literature and will be used in the remainder of this section. The goal of this procedure is to choose as best the computer service which has the smallest a-quantile. For example, a computer service which has a .9-quantile value of 3.2 seconds for response time (i.e., 90% of all response times are 3.2 seconds or less) would be chosen over all other services which had values larger than 3.2 seconds. Selection of the best computer service is accomplished via estimates of a-quantile values which are called sample a-quantiles. The procedure quarantees a probability of correct selection at least P*, provided there is a distance d* between the smallest a-quantile value and all other a-quantile values. The significance of d* in this procedure is similar to its significance in the procedure for selection based on means.

Determination of n, the required number of measurements, using this procedure is accomplished by straight-forward table lookup based on values of k, P* and d*. Appropriate tables for use in computer service selection exist only for .5-quantiles [SOB67] and for .9-quantiles [MAM77] and are provided in Tables 21-26 in Appendix B. The tables for selection based on a-quantiles are very limited at present, but work is currently in progress to produce a more extensive set [DUD79].

This procedure for selection assumes that measurements from each computer service are independent and that the underlying data distributions are continuous, but it makes no other assumptions about the data distributions. The procedure is a two step process:

Step 1: Collect n independent measurements from each of the k computer services under study, where n is determined by table lookup based on analyst supplied values of k, a (for the a-quantile), P* and d*. Calculate the ith sample a-quantile, q(i), for each service, where q(i) is defined as follows. Let the positive integer r be defined by r <= (n+1)a < r+1, and let x_r denote the rth largest measurement. Then

$$q(i) = (r + 1 - (n+1)a)x_r + ((n+1)a - r)x_{r+1}.$$

Step 2: Select the service which produced the smallest sample a-quantile value as the best.

2.4.2.3 Selection Based On Proportions -

In this procedure it is desired to select the best service according to a threshold value of a single criterion, C(thld). Let p(i) represent the true proportion of measurements from computer service i which lie below the threshold value C(thld). The goal of this procedure is to choose as best that computer service which has the largest p(i). For example, suppose C(thld) = 3.0 seconds for a response time criterion. A computer service which has 92% of its response times less than 3.0 seconds would be chosen as best if all other services had smaller proportions of values less than 3.0 seconds. Selection of the best computer service is accomplished via estimates of p(i) which are denoted $\hat{p}(i)$. The procedure guarantees a probability of correct selection at least P*, provided there is a distance d* between the largest and next largest proportion value. The significance of d* in this procedure is similar to its significance in the procedure for selection based on means. Extensive tables and graphs of n for various values of k, d* and P* can be found in SOB57. Values of n appropriate for use in computer service selection have been reproduced in Tables 27-30 and Figures 1-8 in Appendix B.

This procedure for selection assumes that measurements from each service are independent and that measurements from the same computer service have a common probability of being less than C(thld). The procedure makes no assumption about their underlying distribution. The procedure is a four step process:

<u>Step 1</u>: Collect n independent measurements from each of the k computer services, where n is determined by table lookup based on analyst supplied values of k, P* and d*.

<u>Step 2</u>: Let X(i) = number of measurements from service i which are < C(thld).

<u>Step 3</u>: Compute $\hat{p}(i) = X(i)/n$.

<u>Step 4</u>: Select the service which produced the largest estimated proportion value as the best. (In case of ties for the largest $\hat{p}(i)$, the probability statement is satisfied by randomly selecting among the services whose $\hat{p}(i)$ values were tied.)

3.0 A CASE STUDY

A large scale feasibility case study was conducted at the National Bureau of Standards to evaluate the time and cost required to apply the computer service comparison methodology in an actual procurement environment. Four heterogeneous remote access time sharing services were compared: a DEC System-10 running a TOPS-10 Monitor, a Honeywell 6180 running MULTICS, an IBM 360/65 running TSO, and a UNIVAC 1108 running Exec 8. The specifications for the case study and the experimental results are presented here.

3.1 Scenario And Scripts

A scenario for the case study, presented in Table 3, was designed to be reasonably representative of the functional requirements of a real workload (see discussion in section 2.2). The scenario consists of commands representing two types of remote access interactive computing: transaction processing and interactive program development and execution.

Table 3

Scenario for the Case Study

General Specifications: Think time (response-to-stimulus delay) for all user commands is 6 seconds.

File Characteristics: the files listed below are to be resident on the respective systems before the start of script execution.

1. Files for executing a COBOL search of a bibliographic database:
   - SELECT: compiled COBOL program
   - BIB: bibliographic database
   - ACCESS: bibliographic entries to be found
   - CHOSEN: list of entries retrieved
   - RESULT: summary of search

2. Files for executing a FORTRAN version of the BELL benchmark:
   - BELL: compiled FORTRAN program
   - BELLIN: input specifications for the program run
   - BELLOUT: output of program run

3. File for interactive FORTRAN program, INTERA, a source program (with errors) to compute prime numbers

Functional Script:

1. Logon to the system.
2. Execute SELECT.
3. Execute BELL.
4. Copy file INTERA to file INTR1.
5. Edit INTR1, correcting a syntax error by changing line 14 to read: GO TO 10.
6. Edit INTR1, correcting a logical error by changing line 23 to read: PP=PP+1.
7. Compile INTR1.
8. Execute INTR1. This will initiate the following dialogue:

```
            ARE YOU TESTING A NUMBER? (0 or 1)
                       Enter: 0 (CR)
           ARE YOU GENERATING PRIMES? (0 or 1)
                       Enter: 1 (CR)
      LIMIT UNDER WHICH PRIMES ARE TO BE GENERATED:
                      Enter: 100 (CR)
25, 2, 3, 5, 7, 11, 13, 17, 19, 23, 31, 37, 41, 43, 47,
53, 59, 71, 68, 71, 73, 79, 83, 89, 97
            ARE YOU TESTING A NUMBER? (0 or 1)
                       Enter: 0 (CR)
           ARE YOU GENERATING PRIMES? (0 or 1)
                       Enter: 0 (CR)
              DO YOU WANT TO QUIT? (0 or 1)
                       Enter: 1 (CR)
```

9. Delete INTR1 file.
10. Logoff system.

The transaction processing was implemented in a COBOL program which executed a sequential search of a bibliographic database in order to retrieve a given set of entries. The database consists of 2400 records, each of which is 132 characters long. The transaction processing was accomplished by command no. 2 in the scenario (see Table 3). A synthetic module which was capable of being adjusted for varying amounts and types of CPU and I/O activity [BUC69] was executed next (item no. 3 in the scenario). The last section of the scenario (items no. 4-9) consists of commands to debug, compile and execute an interactive FORTRAN program which computes prime numbers.

The translation of the scenario into scripts executable on each computer service required interaction with personnel who possessed a thorough knowledge of the respective operating system. For each computer service two activities were required. First, it was necessary to establish permanent program and data files for use in each script execution (as noted in Table 3). Then, instructions for the actual script execution were determined, sometimes including complicated "control language" constructs.

The specifications for running the scripts are typical of a real selection procedure. The user is often concerned with the quality of the computer service offered during a particular time period. If this quality is within acceptable limits, then service at all other times is assumed to be acceptable. In this case study, the scripts were used to collect performance data from each service only between 8:30 a.m. and 4:45 p.m., Monday through Friday, in order to compare the services under normal work day conditions.

3.2 Data Collection And Analysis

Eight performance measures were chosen for computer service comparison in the case study. They are:

1. cost,

2. turnaround time for the entire script execution,

3. response time for the bibliographic retrieval (no. 2 in the scenario),

4. response time for the FORTRAN program (no. 3 in the scenario),

5. response time for the copy command (no. 4 in the scenario),

6. response time for the first edit command (no. 5 in the scenario),

7. response time for the second edit command (no. 6 in the scenario), and

8. response time for the interactive calculation of all prime numbers less than 100 (no. 8 in the scenario).

3.2.1 Measurement Of Computer Services -

The hardware/software configuration for the case study is illustrated in Figure 2. The scripts were executed on each system under the automatic control of a remote terminal emulator called the Network Access Machine [ROS75]. Turnaround time, response time and cost data were automatically collected for each execution of each script by a minicomputer called the Network Measurement Machine [ABR77a, ROS76]. The data were analyzed using a statistical package called OMNITAB [HOG71]. Correlation coefficients, means, percentiles and proportions were calculated. Since all of the selection procedures described above require independent measurements if the probability of correct selection is to be at least P*, the correlation coefficients were evaluated first. The method of ensuring independence for the experimental data is described in section 3.2.2. Readers are advised to read Appendix A before proceeding with this discussion if they are unfamiliar with correlation. Section 3.3 then presents example applications for each of the procedures described in section 2.4

From this point on, the computer services will be referred to as service A, B, C and D. The letters have been randomly assigned to the four services to ensure their anonymity. The selection results discussed below are primarily a function of the load on a given system and not of the individual hardware/software combinations providing the computer service. Thus, it cannot be concluded from this study that a given computer system is better than the others, but only that a given computer service is better. The results of the case study are not to be construed as an endorsement of any one computer service.

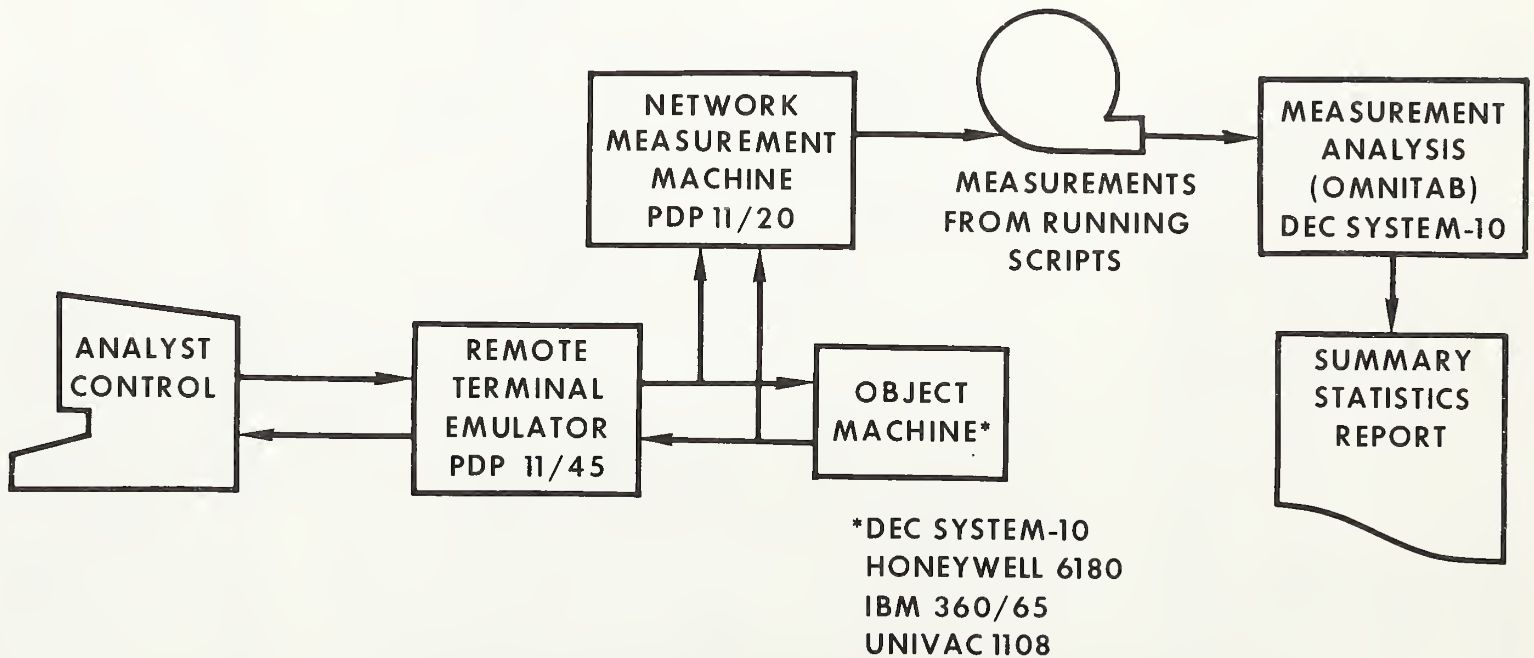

Figure 2. Hardware/Software Configuration for the Case Study

3.2.2 Assessing Correlation -

An experiment was designed so that each script run contributed one measurement for each of the eight measures listed above. Date and time information was also recorded for each script run. Thirty consecutive script runs were performed on each of the four computer services and correlation coefficients (defined in Appendix A) were estimated for each performance measure for each service. These are presented in Table 4. The 95% confidence interval (defined in Appendix A) for a true correlation coefficient of zero when n = 30 was computed to be (-.36,.36). If the estimated correlation values fell within the 95% confidence interval, then for purposes of the case study, the measurements were taken to be independent.

For computer service D all estimated correlation coefficients for all eight measures were within the 95% confidence interval. Thus, it was concluded that these measurements were independent and no care need be taken to space script runs at any minimum time intervals. For the other three computer services, all of the estimated correlation coefficients were not within the 95% confidence interval, thereby invalidating an independence assumption (see Table 4). For these services, thirty more script runs were executed no less than 15 minutes apart. The new interval lengths were chosen in an ad hoc manner based on the average time to run a script on the respective system and on the magnitude of the estimated correlation coefficients from previous script runs. Correlation coefficients were then estimated for the second thirty script runs. For services B and C, the correlation coefficients were found to be within the 95% interval (see Table 4), but service A script runs required an even longer interval between consecutive runs. Thirty more scripts were run on service A no less than 40 minutes apart and finally no less than 60 minutes apart to obtain measurements that could be assumed independent.

Measurement collection then proceeded on all computer services according to a schedule that maintained the minimum interval required for each service for independent measurements. Since the purpose of the experiment was to demonstrate several selection procedures, each of which might require a different number of measurements, a maximum number anticipated for any selection process of 120 was collected from each computer service. Thus, a script was run 120 times on each of the four systems. (In a real application of these procedures the exact number of measurements is determined in advance based on the predefined performance criteria.) Using a 99% confidence interval, data independence was tested on the set of 120 observations. These included the set of 30 data points that were initially taken to be independent for each performance

Table 4

Estimated Correlation Coefficients (n=30)

Computer Service

Performance Measure (see section 3.2)	D	C		B		A		
	Spacing none	Spacing none	Spacing 15 min.	Spacing none	Spacing 15 min.	Spacing none	Spacing 40 min.	Spacing 60 min.
Cost	-.1325	.3957	.2535	.6420	.3594	.8281	.4151	.3040
Script turnaround	.0914	.3964	.2548	.6118	.3244	.3944	.3480	.2660
Bibliographic retrieval	-.0367	.1938	.0221	-.0571	-.0536	-.0118	.2095	.0645
FORTRAN program	-.0533	.1422	-.0270	-.1012	.0884	.2903	.2824	.2554
Copy	-.2948	.0469	-.0365	.2304	.0225	.3124	.2078	.0292
First edit	-.0207	.2345	-.1678	*	*	.1164	.0395	-.1229
Second edit	-.0521	-.1539	-.0584	*	*	.1948	.1597	.1047
Calculation of primes	.0191	.1040	.1102	-.0332	-.0221	.3486	.2744	.3047

*All values of these measures were identical, and so the correlation coefficient is undefined.

measure. For services C and D, a data independence assumption had been maintained, but for services A and B the correlation coefficients for some of the performance measurements did not fall within the 99% confidence interval. For these two services, the 90 most widely spaced script runs (of the 120) were determined, and these new data sets were again tested for independence. In both cases, independence could be assumed for these reduced data sets. For simplicity in the presentation of example applications in section 3.3, the data sets from computer services C and D were also reduced to 90 points (the first 90 points is each case).

In general, the computer services with a relatively uniform load throughout the measurement period had the lowest estimated correlation coefficients. For those services whose load varied widely with the time of day, the correlation estimates were highest. In these latter cases, scripts which were run in quick succession tended to produce "runs" of measurements either below the mean (light loading) or above the mean (heavy loading). As discussed in Appendix A, it is just this type of data that is likely to be correlated. Thus, an analyst should take extra care to widely space script runs on computer services whose loading varies widely.

3.3 Comparison Results

Table 5 presents various summary statistics for the four computer services. Many of these statistics were used in the examples below. The rest are presented to provide a complete comparison picture. All of the statistics are based on 90 measurements. Since 90 independent measurements were available for all performance variables on all computer services, all 90 of them are used in the examples below, even though in some cases fewer were required for a given level of confidence. It is statistically acceptable to use more than the required number of measurements, and advisable to do so if they are available.

In the examples, the values of those parameters which are to be chosen by an analyst were arbitrarily specified. However, they represent values that are likely to be chosen in a computer service selection process. The steps in the examples parallel the steps in the original presentation of the procedures in section 2.4. In references to the "ith computer service", i assumes the values A through D (rather than 1 through 4).

Table 5

Sample Statistics from the Case Study

Variable	Computer Service	Mean	.5-quantile (Median)	.9-quantile	No. Measurements <C(thld)
					C(thld) = 2.00
1. Cost ($)	A	3.44	3.93	4.51	13
	B	.81	.76	1.08	90
	C	1.69	1.64	2.43	67
	D	1.72	1.71	1.81	87
					C(thld) = 10.00
2. Script turnaround (min.)	A	4.53	4.35	5.69	90
	B	4.97	4.55	7.52	89
	C	12.77	12.32	18.21	32
	D	7.85	7.70	10.36	77
					C(thld) = 10.00
3. Response time for bibliographic retrieval (sec.)	A	10.63	9.33	18.46	52
	B	1.08	.66	2.52	90
	C	147.82	116.41	254.17	0
	D	6.36	3.37	12.19	80
					C(thld) = 30.00
4. Response time for FORTRAN synthetic program (sec.)	A	12.91	10.06	28.10	84
	B	1.19	.80	2.60	90
	C	30.27	21.31	50.61	56
	D	11.32	7.00	20.22	84
					C(thld) = 3.00
5. Response time for copy command (sec.)	A	2.27	1.59	3.99	71
	B	2.53	2.05	4.45	69
	C	23.74	18.54	44.32	0
	D	4.26	3.69	9.12	43
					C(thld) = 3.00
6. Response time for first edit (sec.)	A	1.24	.92	2.63	84
	B	.15	.15	.15	90
	C	4.18	2.74	9.49	50
	D	3.50	2.06	6.27	57
					C(thld) = 3.00
7. Response time for second edit (sec.)	A	1.05	.64	1.93	87
	B	.15	.15	.15	90
	C	4.38	2.54	8.13	62
	D	3.63	1.82	4.87	61
					C(thld) = 1.00
8. Response for calculation of prime numbers (sec.)	A	1.21	.92	2.37	49
	B	.13	.12	.15	90
	C	.76	.60	1.30	74
	D	2.62	1.66	6.80	32

3.3.1 Selection Of Services Satisfying A Mandatory Requirement: Based On Proportions -

<u>Example</u>
(parallels section 2.4.1)

<u>Step</u> <u>1</u>: Suppose it is a mandatory requirement that a computer service be able to interactively calculate the prime numbers between 1 and 100 (no. 8 in Table 5) in less than 1.00 second at least 80% of the time. Further, suppose it is desired to select a subset containing all such services with a probability of correct selection at least .90. Then P* = .90, C(thld) = 1.00 and p(min) = .80.

<u>Step</u> <u>2</u>: Choose n = 90. Ninety independent measurements have been made on each computer service.

<u>Step</u> <u>3</u>: For the computer services under study, X(A) = 49, X(B) = 90, X(C) = 74 and X(D) = 32.

<u>Step</u> <u>4</u>: Table 3 in Appendix B shows that M = 64 for this example. Therefore select services B and C and reject services A and D.

<u>Example</u>
(parallels section 2.4.1)

<u>Step</u> <u>1</u>: Suppose it is a mandatory requirement that a computer service be able to process the first edit command (no. 6 in Table 5) in less than 3.00 seconds at least 70% of the time. So, C(thld) = 3.00 and p(min) = .70. Let P* = .95.

<u>Step</u> <u>2</u>: Choose n = 90. Ninety independent measurements have been made on each computer service.

<u>Step</u> <u>3</u>: For the four computer services, X(A) = 84, X(B) = 90, X(C) = 50 and X(D) = 57.

<u>Step</u> <u>4</u>: Table 3 in Appendix B shows that M = 53 for this example. Therefore, select services A, B and D and reject service C. Note that if ranking and selection techniques were not being applied in this example, then service D might have been rejected since 70% of 90 is 63 and X(D) < 63. But the ranking and selection procedure indicates that because of experimental variation service D cannot be rejected at the 95% confidence level.

3.3.2 Selection Of The Best Service -

3.3.2.1 Selection Based On Means -

<u>Example</u>
(parallels section 2.4.2.1)

<u>Step 1</u>: Suppose it is desired to select the computer service which has the lowest mean cost (no. 1 in Table 5) from among services B, C and D. (Service A already may have been rejected in an earlier selection process.) This procedure for selection is applicable only if the measurements are normal, so a Kolmogorov-Smirnov test for normality was applied to the cost data from computer services B, C and D. Sample results for computer service C are presented in Table 6. The test is described fully in many statistics textbooks (BRA68 has a particularly good discussion). The cost data from all three services passed the Kolmorgorov-Smirnov test at a confidence level of .95. The first stage sample means (n1 = 30) from each service were $\overline{x1}(B) = .80$, $\overline{x1}(C) = 1.64$ and $\overline{x1}(D) = 1.74$. The sample variances were $s^2(B) = .20$, $s^2(C) = .53$ and $s^2(D) = .17$.

<u>Step 2</u>: Choose P* = .95 and d* = .25 (this d* value implies that an analyst wishes to detect differences in cost greater than $0.25). For n1 = 30 and k=3, Table 20 in Appendix B shows that h = 2.81. Using h to calculate the total number of measurements required from each service yields:

$$n(B) = \max[\ 31,\ ((.45)(2.81)/.25)^2] = 31$$

$$n(C) = \max[\ 31,\ ((.73)(2.81)/.25)^2] = 68$$

$$n(D) = \max[\ 31,\ ((.42)(2.81)/.25)^2] = 31$$

<u>Step 3</u>: Service C requires (68-30) more data points and services B and D require one more measurement each. Since 90 independent measurements already exist for each computer service, use (90-30) more measurements to calculate the second stage means for every service. Hence, $\overline{x2}(B) = .81$, $\overline{x2}(C) = 1.76$ and $\overline{x2}(D) = 1.70$.

<u>Step 4</u>: The weighted mean for each service is $\overline{x}(B) = .81$, $\overline{x}(C) = 1.69$ and $\overline{x}(D) = 1.72$.

<u>Step 5</u>: Select service B as the best.

Table 6

Example Kolmogorov-Smirnov Test for Normality: Service C Cost Data

Cost Interval ($)	Observed Frequency (n=90)	Observed Cumulative Frequency	Observed Cumulative Distribution	Theoretical Cumulative Distribution Normal (1.70,0.67)	$\lvert D \rvert$
0.00-0.83	1	1	0.01	0.10	0.09
0.84-1.13	17	18	0.20	0.20	0.00
1.14-1.34	15	33	0.37	0.30	0.07
1.35-1.52	8	41	0.46	0.40	0.06
1.53-1.69	6	47	0.52	0.50	0.02
1.70-1.87	11	58	0.64	0.60	0.04
1.88-2.05	14	72	0.80	0.70	0.10
2.06-2.26	6	78	0.87	0.80	0.07
2.27-2.56	5	83	0.92	0.90	0.02
$\geq$ 2.57	7	90	1.00	1.00	0.00

$$\lvert D \rvert_{max} = 0.10 < D_{(90,0.95)} = 0.14117$$

<u>Example</u>
(parallels section 2.4.2.1)

<u>Step 1</u>: Suppose it is desired to select the computer service which has the lowest mean turnaround time (no. 2 in Table 5) from among services A, B and D. The turnaround time data from these three services passed the Kolmorgorov-Smirnov test for normality at a confidence level of .95. The first stage sample means from each service were $\overline{x1}(A) = 4.63$, $\overline{x1}(B) = 4.92$ and $\overline{x1}(D) = 7.87$. The sample variances were $s^2(A) = .82$, $s^2(B) = 1.96$ and $s^2(D) = 1.74$.

<u>Step 2</u>: Choose P* = .90 and d* = .5 (an analyst wishes to detect differences of .5 minutes). For n1 = 30 and k = 3, Table 20 in Appendix B shows that h = 2.30. Using h to calculate the total number of measurements required from each service yields:

$$n(A) = \max[\ 31,\ ((.91)(2.30)/.5)^2] = 31$$

$$n(B) = \max[\ 31,\ ((1.39)(2.30)/.5)^2] = 41$$

$$n(D) = \max[\ 31,\ ((1.32)(2.30)/.5)^2] = 37$$

<u>Step 3</u>: As in the previous example, since 90 measurements have been made on each computer service, use (90-30) measurements for the second stage means for all services. Hence $\overline{x2}(A) = 4.48$, $\overline{x2}(B) = 5.00$ and $\overline{x2}(D) = 7.72$.

<u>Step 4</u>: The weighted mean for each service is $\bar{x}(A) = 4.53$, $\bar{x}(B) = 4.97$ and $\bar{x}(D) = 7.85$.

<u>Step 5</u>: Select service A as the best.

3.3.2.2 Selection Based On Percentiles -

<u>Example</u>
(parallels section 2.4.2.2)

<u>Step 1</u>: Suppose it is desired to select the computer service which has the lowest median value for response time to execute the bibliographic retrieval (no. 3 in Table 5). Then a = .5. Choose P* = .90 and d* = .15. For k = 4, Table 22 in Appendix B indicates that n = 67 independent measurements are required from each service. Since 90 measurements already exist for each computer service, use 90 measurements. Hence, q(A) = 9.33, q(B) = .66, q(C) = 116.41 and q(D) = 3.37.

Step 2: Select service B as the best.

Example
(parallels section 2.4.2.2)

Step 1: Suppose it is desired to select between services A and D the computer service which has the lowest .9-quantile value for response time to the second edit command (no. 7 in Table 5). Than a = .9. Choose P* = .75 and d* = .04. For k = 2, Table 25 in Appendix B indicates that n = 69 independent measurements are required from each service. Since 90 measurements exist, use all 90 to calculate q(A) = 1.93 and q(D) = 4.87.

Step 2: Select service A as the best.

3.3.2.3 Selection Based On Proportions -

Example
(parallels section 2.4.2.3)

Step 1: Suppose it is desired to select the computer service which has the largest proportion of response times for the execution of the FORTRAN program (no. 4 in Table 5) which are less than 30.00 seconds. Then C(thld) = 30.00. Assume that P* = .80 and d* =.10. Table 29 in Appendix B indicates that for this example n = 90 independent measurements are required from each service.

Step 2: For the four computer services, X(A) = 84, X(B) = 90, X(C) = 56 and X(D) = 84.

Step 3: For the four computer services, $\hat{p}$(A) = X(A)/n = 84/90 = .93, $\hat{p}$(B) = 1.00, $\hat{p}$(C) = .62 and $\hat{p}$(D) = .93.

Step 4: Select service B as the best.

Example
(parallels section 2.4.2.3)

Step 1: Suppose it is desired to select the computer service which has the largest proportion of response times for the copy command (no. 5 in Table 5) which are less than 3.00 seconds. Then C(thld) = 3.00. Assume that P* = .80 and d* = 10. Then Table 28 in Appendix B indicates that n = 69 independent measurements are required from each service. The total 90 measurements will be used.

Step 2: For the four computer services, X(A) = 71, X(B) = 69, X(C) = Ø and X(D) = 43.

Step 3: For the four computer services, $\hat{p}(A)$ = .78, $\hat{p}(B)$ = .75, $\hat{p}(C)$ = Ø.Ø and $\hat{p}(D)$ = .48.

Step 4: Select service A as the best.

4.Ø DISCUSSION AND CONCLUSIONS

4.1 Estimated Cost Of Using The Methodology

The total cost of the case study was estimated to be $16,6ØØ. Personnel and equipment costs are itemized according to different tasks in Table 7. Each task was performed by one professional and one technical person working in cooperation on a full time basis. Personnel costs are estimated at $2ØØ/day for each person. This represents the averaged "burdened" (all overhead included) cost to the Federal Government per day for each person.

In a typical procurement study, the equipment cost from developing and running the scripts would be absorbed by the vendors. Therefore, although these costs are noted in Table 7, no figures are entered. It is assumed that the equipment costs for the data collection and analysis are part of a selection effort. These activities require a specialized hardware and software configuration for about six weeks, with an estimated cost of $1,5ØØ.

Since care was taken to design and execute the case study in the same way that a real procurement would be done, the total cost figure of $16,6ØØ covers the measurement phases of a full-scale procurement study. This figure, therefore, can be used as a basis for a reasonable cost estimate when making a decision about using the selection methodology in any real procurement. The impact on cost due to an increase in the number of computer services or due to a change in the number of selection criteria is discussed below.

If more than four computer services are to be compared, then various personnel and equipment costs will change, but in different proportions. Time for scenario development will remain the same since only one scenario is needed regardless of the number of services. The time required for script generation and for writing control programs for remote terminal emulation will increase in direct proportion to the increase in the number of services being compared. This is because time is necessary to translate the scenario into a system compatible script for each service. The total elapsed time for data collection (script runs) may remain

Table 7

Estimated Cost

a. Personnel

Task	Person Days	Cost ($200/day)
Scenario development	5	$ 1000
Script generation (4 computer services)	12	2400
Control programs for remote terminal emulator	8	1600
Script runs (data collection)	30	6000
Data analysis	15	3000
Report generation	3	600
Overhead (equipment failure, bad data etc.)	2	400
	75	$ 15000

b. Equipment

Task	Cost ($)
Script development (4 computer services)	*
Script runs (150 runs/service)	*
Data collection and analysis	$ 1600
	$ 1600

Total Cost = $15,000 + $1,600 = $16,600

*Supplied by the vendor

the same, or increase slightly, inasmuch as the requirement for independent measurements forces spacing of script runs anyway. As more time is required to collect measurements, more money must be allocated for data collection equipment. The total increase for both data analysis and report generation would be about two more person days for each additional computer service.

A change in the number of selection criteria to be applied will not have much impact on the cost of the study. Most automatic measurement devices collect data about every interactive transaction, even if it is not all required. So, increasing or decreasing the number of criteria actually used in the selection has little effect on the time and cost of data collection. Also, most statistical analysis packages are as easy to run for one variable as for ten, so changing the number of criteria will have little effect on the time and cost of data analysis.

4.2 Applicability Of Techniques

All of the techniques for selection of the best computer service (section 2.4.2) require that the analyst supply a value indicating how close together the best service and any other service(s) can be before they are considered equivalent from both a statistical and a practical viewpoint. This value is represented by the parameter d*. The statistical theory has been derived such that a correct selection is defined to be either the best service, or any other service that is within d* of the best. Since the analyst chooses d* to be that value for which it is not cost-effective or desirable to distinguish among the services, this is an acceptable solution from one point of view. The methodology guarantees selection of the best, but when several services are close to the best (specifically within d* of the best) the best may not be unique.

From another point of view, however, the statistical solution may not be acceptable. This is true, for example, if selection as the best implies being awarded several points toward a final merit value, while all other services are awarded no points. If this kind of point system is used, as is often the case in Federal Government procurement, <u>all</u> services which are within d* of the best, and are both practically and statistically equivalent to the best, should be awarded points. Hence, in certain circumstances, depending on the selection objective, it is possible that ranking and selection techniques for choosing the best should not be used.

As an alternative, the subset selection technique (section 2.4.1) can be applied in selection phase IIIB. When applying the technique to mandatory criteria in phase II, those services which meet the criteria are selected for the next phase and those which do not meet the criteria are eliminated. In phase IIIB, those services which meet the criteria can be awarded an equal number of points, and those which do not can be awarded no points.

4.3 General Recommendations

The selection methodology presented in this publication is important because it provides statements about the probability of having made a correct selection. The number of independent measurements required from each computer service in a comparison is clearly specified for a given level of confidence in the selection results. If it is determined prior to the measurement phase of a procurement study that, due to either time or cost constraints, a required number of measurements cannot be made, then it is not an unreasonable decision to eliminate the entire measurement phase from the selection process.

A collection of measurements can often give an illusion of fairness and objectivity to a computer service selection when in reality the measurements contain little information of value. This can be the case when a selection is based on methods and techniques which are not statistically sound. Suppose, for example, that an analyst executes thirty script runs on a computer service, intending to use the measurements which result as a fair and objective evaluation of that service. Suppose also that these runs are performed in quick succession to "save time". As was demonstrated in this case study, it is possible that as few as two or three of the thirty measurements are independent because "saving time" may result in too short a spacing interval. In a situation where too short a spacing interval is used, thirty measurements may be quoted as the basis for an evaluation, but in reality the actual information is equivalent to that provided by a much smaller set of measurements. Thus, only an illusion of fairness and objectivity exists.

So, if statistically sound methods cannot be applied to the measurement phases of the selection process, it may be more effective to concentrate on the other phases of the selection process (phase I and IIIA in Figure 1) than to waste time and money producing measurements which are of questionable value.

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APPENDIX A

Correlation

The independence of a set of measurements can be assessed by calculating a statistic called the correlation coefficient [GEI62]. The correlation coefficient for n measurements can be estimated by:

$$(A1)\quad \hat{r} = \frac{\sum_{i=1}^{n-1} (x(i) - \bar{x})\,(x(i+1) - \bar{x})}{s^2(n-1)}$$

where i = 1,2,...,n, $\bar{x}$ is the sample mean and s^2 is the sample variance of the data. The correlation coefficient is alternatively called the autocorrelation coefficient, and is a measure of the correlation between adjacent data points. A method for testing if the data are independent is to find the 100(1-a)% (0 <= a <= 1) confidence interval for the true correlation coefficient, r. If the estimated correlation coefficient falls within the interval, then the data can be taken to be independent. To form this confidence interval for any value of r, determine if:

$$(A2)\quad (r - \hat{r})^2 \leq \frac{n-1}{n(n-3)} (1-\hat{r}^2)\; t^2\left(n-3, 1-\frac{a}{2}\right)$$

where t(d,q) is the 100q percent point of the Student's-t distribution with d degrees of freedom.

Independence of the data is an underlying assumption in almost all ranking-and-selection techniques. When measurements are not independent, more observations are required to come within a desired confidence interval for having made a correct choice. The problem of correlation has been addressed in the case of ranking based on means [DUD77] and an expression for the increased sample size has been derived. Dudewicz found that for a comparable level of confidence in the results a comparison based on measurements which are even slightly correlated ($\hat{r}$ = 0.3) required twice as much data as a comparison based on independent measurements. No such theoretical work has been done to handle correlation in the ranking procedures based on percentiles or proportions.

The one approach for dealing with a correlation problem is to design an experiment so as to be reasonably sure that the data as collected are independent. Series of performance measurements which are consistently below or above the mean of the measurements suggest correlation.

There are some system conditions under which this sort of behavior can be anticipated. In order to reduce correlation in the data, therefore, data collection should be avoided, or at least minimized, under these conditions, if such action is compatible with the experiment's objective. Two such periods to be avoided are the times immediately after system start-up and immediately before an announced system shut-down. Another obvious measurement period to be avoided is the recovery time after a major system crash. In this period system usage is inevitably heavier than normal as users try to re-establish their previous working environments.

Not all conditions which may lead to correlated observations can be so readily recognized and avoided. Periodic factors in workload with respect to the time of day, week, month or year, may also cause correlated measurements. Discussion with system support personnel, or frequent system users, is often sufficient to discover what these factors may be. Whenever possible, the experiment should then be designed so as to avoid data collection during these times.

Since correlation is essentially introduced into the observations because they are collected too close together in time, a further means for avoiding correlation is to collect data such that the time between consecutive measurements is as large as is practically possible. For example, if measurements are being taken on several different systems, then alternating them in a round-robin fashion will produce a natural spacing interval. Or, if several measurements of different kinds are being made on a single system, then a similar spacing technique can be incorporated.

An estimate of the minimum required spacing between consecutive measurements in order to prevent correlation can be made by running a pretest in which 30 measurements are collected in succession. The estimated correlation coefficient can then be used to determine if measurements are independent and this information can be translated into a spacing interval. There are no strict rules for choosing an interval of adequate length, but previous experience suggests that if successive runs are correlated, then choosing an interval that is about three times as long as the average script run itself, is a good first estimate. Thirty more measurements should be collected with this minimum interval between data points and again tested for correlation. This process should continue until an interval which produces independent measurements is derived.

APPENDIX B
Tables

This appendix contains tabled values which are most likely to be needed to apply the ranking and selection procedures described in this publication to computer service selection. The tables are arranged to parallel the description of the procedures in section 2.4 and the example applications of the procedures in section 3.3. The notation used in each table is consistent with that used in section 2.4, with a few noted exceptions. A demonstration of the use of each set of tables can be found in section 3.3.

The tables, with their original source noted in brackets, are divided up in the following way (all tables reproduced with permission of the copyright holder):

Table 1-19 [AME78a]:	Selection of computer services satisfying a mandatory requirement based on proportions; in all of these tables, the notation P(CS) represents "the probability of correct selection" and the standard proportion refers to p(min).
Table 20 [DUD75]:	Selection of the best computer service based on means. Copyright 1975, Akadamie-Verlag.
Tables 21-26 [SOB67]:	Selection of the best computer service based on percentiles. Copyright 1967, Institute of Mathematical Statistics.
Tables 27-30 and Figures 1-8 [SOB57]:	Selection of the best computer service based on proportions. Reprinted with permission from the Bell System Technical Journal, Copyright 1957 , The American Telephone and Telegraph Company.

In those cases where values other than the ones tabulated are desired, the analyst is encouraged to refer to the original source. If the desired values do not appear in the original source, they may be in preparation and the analyst is advised to consult the authors of this publication.

TABLE 1

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 2 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	1	1	2	2	3
10	0	0	1	2	2	3	5	6	7
15	0	1	2	3	4	6	8	9	11
20	0	1	3	5	6	8	11	13	16
25	0	2	4	6	8	11	14	17	20
30	1	3	5	8	11	14	17	20	24
35	1	3	6	9	13	16	20	24	28
40	1	4	7	11	15	19	23	28	33
45	1	5	9	13	17	22	26	31	37
50	2	6	10	14	19	24	30	35	41
60	2	7	12	18	24	30	36	43	50
70	3	9	15	21	28	35	43	50	59
80	4	10	17	25	33	41	49	58	67
90	5	12	20	28	37	46	56	66	76
100	5	14	23	32	42	52	62	73	85

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	3	4	5	6
15	0	0	1	2	3	5	6	8	10
20	0	1	2	3	5	7	9	12	15
25	0	1	3	5	7	9	12	15	19
30	0	2	4	6	9	12	15	19	23
35	0	2	5	8	11	14	18	22	27
40	0	3	6	9	13	17	21	26	31
45	1	3	7	11	15	20	24	30	36
50	1	4	8	12	17	22	28	33	40
60	1	6	10	16	21	27	34	41	48
70	2	7	13	19	26	33	40	48	57
80	3	8	15	22	30	38	47	56	66
90	3	10	18	26	34	44	53	63	74
100	4	12	20	29	39	49	60	71	83

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	3	4	5	7
15	0	0	1	2	4	5	7	9	11
20	0	1	2	4	6	8	10	12	15
25	0	1	3	5	8	10	13	16	19
30	0	2	4	7	10	13	16	19	23
35	1	3	5	8	12	15	19	23	28
40	1	3	7	10	14	18	22	27	32
45	1	4	8	12	16	21	25	31	36
50	1	5	9	13	18	23	29	34	41
60	2	6	11	17	22	29	35	42	49
70	3	8	14	20	27	34	41	49	58
80	3	9	16	24	31	39	48	57	66
90	4	11	19	27	36	45	54	64	75
100	5	12	21	31	40	50	61	72	84

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	1	1	3	4	6	8	10
20	0	0	1	3	4	6	8	11	14
25	0	1	2	4	6	9	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	2	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	30
45	0	3	6	10	14	18	23	29	35
50	0	3	7	11	16	21	26	32	39
60	1	5	9	15	20	26	33	40	47
70	1	6	12	18	24	31	39	47	56
80	2	7	14	21	29	37	45	54	64
90	3	9	16	24	33	42	51	62	73
100	3	10	19	28	37	47	58	69	82

TABLE 2

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 3 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	1	1	2	2	3
10	0	0	1	1	2	3	4	6	7
15	0	0	1	3	4	6	7	9	11
20	0	1	2	4	6	8	10	13	15
25	0	2	4	6	8	11	13	16	20
30	0	2	5	7	10	13	16	20	24
35	1	3	6	9	12	16	19	24	28
40	1	4	7	10	14	18	23	27	32
45	1	4	8	12	16	21	26	31	37
50	2	5	9	14	19	24	29	35	41
60	2	7	12	17	23	29	35	42	50
70	3	8	14	21	27	34	42	50	58
80	3	10	17	24	32	40	48	57	67
90	4	11	19	28	36	45	55	65	76
100	5	13	22	31	41	51	62	73	84

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	2	2
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	4	6	8	10
20	0	0	2	3	5	7	9	11	14
25	0	1	2	4	7	9	12	15	18
30	0	1	3	6	9	12	15	18	23
35	0	2	4	7	11	14	18	22	27
40	0	3	5	9	13	17	21	26	31
45	0	3	7	10	15	19	24	29	35
50	1	4	8	12	17	22	27	33	39
60	1	5	10	15	21	27	33	40	48
70	2	7	12	18	25	32	40	48	56
80	2	8	15	22	29	37	46	55	65
90	3	9	17	25	34	43	52	63	74
100	4	11	19	28	38	48	59	70	82

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	3	4	5	7
15	0	0	1	2	3	5	7	8	11
20	0	1	2	4	5	7	9	12	15
25	0	1	3	5	7	10	12	15	19
30	0	2	4	6	9	12	16	19	23
35	0	2	5	8	11	15	19	23	27
40	1	3	6	10	13	17	22	26	32
45	1	4	7	11	15	20	25	30	36
50	1	4	8	13	18	23	28	34	40
60	2	6	11	16	22	28	34	41	49
70	2	7	13	19	26	33	41	49	57
80	3	9	16	23	31	39	47	56	66
90	4	10	18	26	35	44	54	64	75
100	4	12	21	30	39	50	60	71	83

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	1	4	6	10	13	17	21	26
40	0	2	5	8	12	15	20	25	30
45	0	3	6	9	14	18	23	28	34
50	0	3	7	11	16	20	26	32	39
60	1	4	9	14	20	26	32	39	47
70	1	6	11	17	24	31	38	46	55
80	2	7	13	20	28	36	45	54	64
90	2	8	16	24	32	41	51	61	73
100	3	10	18	27	37	47	57	69	81

TABLE 3

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 4 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

STANDARD PROPORTION

NUMBER OF OBSERVATIONS (N)	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	3	4	5	7
15	0	0	1	2	4	5	7	9	11
20	0	1	2	4	6	8	10	12	15
25	0	1	3	5	8	10	13	16	19
30	0	2	4	7	10	13	16	20	24
35	1	3	5	9	12	15	19	23	28
40	1	3	7	10	14	18	22	27	32
45	1	4	8	12	16	21	25	31	36
50	1	5	9	13	18	23	29	34	41
60	2	6	11	17	23	29	35	42	49
70	3	8	14	20	27	34	41	49	58
80	3	9	16	24	31	39	48	57	66
90	4	11	19	27	36	45	54	64	75
100	5	13	21	31	40	50	61	72	84

P* = .975

STANDARD PROPORTION

NUMBER OF OBSERVATIONS (N)	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	1	1	2	3	4	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	5	6	9	11	14
25	0	1	2	4	6	9	12	15	18
30	0	1	3	6	8	11	14	18	22
35	0	2	4	7	10	14	17	22	27
40	0	2	5	9	12	16	21	25	31
45	0	3	6	10	14	19	24	29	35
50	1	4	7	12	16	21	27	33	39
60	1	5	10	15	20	26	33	40	48
70	2	6	12	18	25	32	39	47	56
80	2	8	14	21	29	37	45	55	65
90	3	9	17	25	33	42	52	62	73
100	3	11	19	28	38	48	58	70	82

P* = .950

STANDARD PROPORTION

NUMBER OF OBSERVATIONS (N)	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	3	4	5	6
15	0	0	1	2	3	5	6	8	11
20	0	1	2	3	5	7	9	12	15
25	0	1	3	5	7	9	12	15	19
30	0	2	4	6	9	12	15	19	23
35	0	2	5	8	11	14	18	22	27
40	0	3	6	9	13	17	21	26	31
45	1	3	7	11	15	20	24	30	36
50	1	4	8	12	17	22	28	33	40
60	1	6	10	16	21	27	34	41	48
70	2	7	13	19	26	33	40	48	57
80	3	8	15	22	30	38	47	56	66
90	3	10	18	26	34	44	53	63	74
100	4	12	20	29	39	49	60	71	83

P* = .990

STANDARD PROPORTION

NUMBER OF OBSERVATIONS (N)	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	10	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	7	10	14	17	22
35	0	1	4	6	9	13	17	21	26
40	0	2	4	8	11	15	20	24	30
45	0	2	5	9	13	18	23	28	34
50	0	3	7	11	15	20	26	31	38
60	1	4	9	14	19	25	32	39	47
70	1	5	11	17	23	30	38	46	55
80	2	7	13	20	28	36	44	53	64
90	2	8	15	23	32	41	50	61	72
100	3	10	18	27	36	46	57	68	81

TABLE 4

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 5 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	3	4	5	7
15	0	0	1	2	4	5	7	9	11
20	0	1	2	4	6	7	10	12	15
25	0	1	3	5	7	10	13	16	19
30	0	2	4	7	9	12	16	19	23
35	0	3	5	8	12	15	19	23	28
40	1	3	6	10	14	18	22	27	32
45	1	4	7	11	16	20	25	30	36
50	1	5	9	13	18	23	28	34	40
60	2	6	11	16	22	28	35	41	49
70	2	8	13	20	27	34	41	49	58
80	3	9	16	23	31	39	47	56	66
90	4	11	18	27	35	44	54	64	75
100	4	12	21	30	40	50	60	72	84

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	1	1	3	4	6	8	10
20	0	0	1	3	4	6	8	11	14
25	0	1	2	4	6	9	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	2	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	30
45	0	3	6	10	14	18	23	29	35
50	0	3	7	11	16	21	26	32	39
60	1	5	9	15	20	26	33	40	47
70	1	6	12	18	24	31	39	47	56
80	2	7	14	21	29	37	45	54	64
90	3	9	16	24	33	42	52	62	73
100	3	10	19	28	37	47	58	69	82

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	2	3
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	5	6	8	10
20	0	0	2	3	5	7	9	12	14
25	0	1	3	5	7	9	12	15	19
30	0	1	4	6	9	12	15	19	23
35	0	2	5	8	11	14	18	22	27
40	0	3	6	9	13	17	21	26	31
45	1	3	7	11	15	19	24	29	35
50	1	4	8	12	17	22	27	33	40
60	1	5	10	15	21	27	34	40	48
70	2	7	12	19	25	32	40	48	57
80	2	8	15	22	30	38	46	55	65
90	3	10	17	25	34	43	53	63	74
100	4	11	20	29	38	49	59	70	83

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	9
20	0	0	1	2	4	6	8	10	13
25	0	0	2	3	5	8	11	14	17
30	0	1	2	5	7	10	13	17	21
35	0	1	3	6	9	13	16	21	26
40	0	2	4	7	11	15	19	24	30
45	0	2	5	9	13	17	22	28	34
50	0	3	6	10	15	20	25	31	38
60	1	4	8	13	19	25	31	38	46
70	1	5	11	17	23	30	38	46	55
80	1	7	13	20	27	35	44	53	63
90	2	8	15	23	31	40	50	60	72
100	3	9	17	26	36	46	56	68	81

TABLE 5

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 6 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	3	4	5	7
15	0	0	1	2	3	5	7	8	11
20	0	1	2	4	5	7	10	12	15
25	0	1	3	5	7	10	12	16	19
30	0	2	4	7	9	12	16	19	23
35	0	2	5	8	11	15	19	23	27
40	1	3	6	10	13	17	22	26	32
45	1	4	7	11	15	20	25	30	36
50	1	4	8	13	18	23	28	34	40
60	2	6	11	16	22	28	34	41	49
70	2	7	13	20	26	33	41	49	57
80	3	9	16	23	31	39	47	56	66
90	4	10	18	26	35	44	54	64	75
100	4	12	21	30	39	50	60	71	83

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	3	4	6	7	10
20	0	0	1	3	4	6	8	11	14
25	0	1	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	2	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	30
45	0	3	6	10	14	18	23	28	35
50	0	3	7	11	16	21	26	32	39
60	1	5	9	14	20	26	32	39	47
70	1	6	11	17	24	31	39	47	56
80	2	7	14	21	28	36	45	54	64
90	2	9	16	24	33	42	51	61	73
100	3	10	18	27	37	47	58	69	81

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	2	2
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	4	6	8	10
20	0	0	2	3	5	7	9	11	14
25	0	1	2	4	7	9	12	15	18
30	0	1	3	6	9	12	15	18	23
35	0	2	4	7	11	14	18	22	27
40	0	3	5	9	13	17	21	26	31
45	0	3	7	10	15	19	24	29	35
50	1	4	8	12	17	22	27	33	39
60	1	5	10	15	21	27	33	40	48
70	2	7	12	18	25	32	40	48	56
80	2	8	15	22	29	37	46	55	65
90	3	9	17	25	34	43	52	63	74
100	4	11	19	29	38	48	59	70	82

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	3	4	6
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	4	6	8	10	13
25	0	0	2	3	5	8	10	14	17
30	0	1	2	5	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	2	4	7	11	15	19	24	30
45	0	2	5	9	13	17	22	28	34
50	0	3	6	10	15	20	25	31	38
60	0	4	8	13	19	25	31	38	46
70	1	5	10	16	23	30	37	46	55
80	1	6	13	20	27	35	44	53	63
90	2	8	15	23	31	40	50	60	72
100	2	9	17	26	35	45	56	68	80

TABLE 6

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 7 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	3	4	5	7
15	0	0	1	2	3	5	6	8	11
20	0	1	2	3	5	7	9	12	15
25	0	1	3	5	7	10	12	15	19
30	0	2	4	6	9	12	15	19	23
35	0	2	5	8	11	15	18	23	27
40	1	3	6	9	13	17	22	26	31
45	1	4	7	11	15	20	25	30	36
50	1	4	8	13	17	22	28	34	40
60	2	6	11	16	22	28	34	41	49
70	2	7	13	19	26	33	40	48	57
80	3	9	15	23	30	38	47	56	66
90	3	10	18	26	35	44	53	63	74
100	4	12	20	30	39	49	60	71	83

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	1	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	30
45	0	3	6	9	14	18	23	28	34
50	0	3	7	11	16	21	26	32	39
60	1	4	9	14	20	26	32	39	47
70	1	6	11	17	24	31	38	46	56
80	2	7	13	21	28	36	45	54	64
90	2	9	16	24	32	41	51	61	73
100	3	10	18	27	37	47	57	69	81

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	2	2
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	5	7	9	11	14
25	0	1	2	4	6	9	12	15	18
30	0	1	3	6	8	11	15	18	22
35	0	2	4	7	10	14	18	22	27
40	0	2	5	9	12	16	21	25	31
45	0	3	6	10	14	19	24	29	35
50	1	4	8	12	16	21	27	33	39
60	1	5	10	15	21	27	33	40	48
70	2	6	12	18	25	32	39	47	56
80	2	8	14	22	29	37	46	55	65
90	3	9	17	25	33	43	52	62	73
100	3	11	19	28	38	48	59	70	82

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	4	5	8	10	13
25	0	0	1	3	5	8	10	13	17
30	0	1	2	4	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	1	4	7	11	15	19	24	29
45	0	2	5	9	13	17	22	27	34
50	0	3	6	10	15	20	25	31	38
60	0	4	8	13	19	25	31	38	46
70	1	5	10	16	23	30	37	45	55
80	1	6	12	19	27	35	43	53	63
90	2	8	15	23	31	40	50	60	72
100	2	9	17	26	35	45	56	67	80

TABLE 7

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 8 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	3	4	5	7
15	0	0	1	2	3	5	6	8	11
20	0	1	2	3	5	7	9	12	15
25	0	1	3	5	7	9	12	15	19
30	0	2	4	6	9	12	15	19	23
35	0	2	5	8	11	14	18	22	27
40	0	3	6	9	13	17	21	26	31
45	1	4	7	11	15	20	24	30	36
50	1	4	8	12	17	22	28	33	40
60	1	6	10	16	21	27	34	41	48
70	2	7	13	19	26	33	40	48	57
80	3	8	15	22	30	38	47	56	66
90	3	10	18	26	34	44	53	63	74
100	4	12	20	29	39	49	60	71	83

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	1	4	6	10	13	17	21	26
40	0	2	5	8	11	15	20	25	30
45	0	2	6	9	13	18	23	28	34
50	0	3	7	11	15	20	26	32	38
60	1	4	9	14	20	26	32	39	47
70	1	6	11	17	24	31	38	46	55
80	2	7	13	20	28	36	44	54	64
90	2	8	16	24	32	41	51	61	72
100	3	10	18	27	36	46	57	69	81

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	5	6	9	11	14
25	0	1	2	4	6	9	12	15	18
30	0	1	3	6	8	11	15	18	22
35	0	2	4	7	10	14	17	22	27
40	0	2	5	9	12	16	21	25	31
45	0	3	6	10	14	19	24	29	35
50	1	4	7	12	16	21	27	33	39
60	1	5	10	15	20	26	33	40	48
70	2	6	12	18	25	32	39	47	56
80	2	8	14	21	29	37	46	55	65
90	3	9	17	25	33	42	52	62	73
100	3	11	19	28	38	48	58	70	82

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	3	5	7	10	13
25	0	0	1	3	5	8	10	13	17
30	0	1	2	4	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	1	4	7	11	15	19	24	29
45	0	2	5	9	13	17	22	27	34
50	0	2	6	10	14	19	25	31	38
60	0	4	8	13	18	24	31	38	46
70	1	5	10	16	22	29	37	45	54
80	1	6	12	19	27	35	43	52	63
90	2	7	15	22	31	40	49	60	71
100	2	9	17	26	35	45	56	67	80

TABLE 8

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 9 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	2	2	4	5	6
15	0	0	1	2	3	5	6	8	10
20	0	1	2	3	5	7	9	12	15
25	0	1	3	5	7	9	12	15	19
30	0	2	4	6	9	12	15	19	23
35	0	2	5	8	11	14	18	22	27
40	0	3	6	9	13	17	21	26	31
45	1	3	7	11	15	19	24	30	35
50	1	4	8	12	17	22	27	33	40
60	1	5	10	16	21	27	34	41	48
70	2	7	13	19	26	33	40	48	57
80	3	8	15	22	30	38	46	56	65
90	3	10	17	26	34	43	53	63	74
100	4	11	20	29	39	49	59	71	83

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	10	14	17	22
35	0	1	4	6	9	13	17	21	26
40	0	2	5	8	11	15	20	24	30
45	0	2	6	9	13	18	23	28	34
50	0	3	7	11	15	20	26	32	38
60	1	4	9	14	19	25	32	39	47
70	1	6	11	17	24	31	38	46	55
80	2	7	13	20	28	36	44	54	64
90	2	8	16	23	32	41	51	61	72
100	3	10	18	27	36	46	57	68	81

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	4	6	9	11	14
25	0	1	2	4	6	9	11	15	18
30	0	1	3	6	8	11	14	18	22
35	0	2	4	7	10	14	17	22	26
40	0	2	5	8	12	16	20	25	31
45	0	3	6	10	14	19	23	29	35
50	1	4	7	11	16	21	27	32	39
60	1	5	9	15	20	26	33	40	48
70	2	6	12	18	24	32	39	47	56
80	2	8	14	21	29	37	45	54	65
90	3	9	16	24	33	42	52	62	73
100	3	10	19	28	37	47	58	69	82

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	3	5	7	10	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	1	4	7	11	14	19	24	29
45	0	2	5	8	12	17	22	27	33
50	0	2	6	10	14	19	25	31	38
60	0	4	8	13	18	24	31	38	46
70	1	5	10	16	22	29	37	45	54
80	1	6	12	19	26	34	43	52	63
90	2	7	14	22	31	40	49	60	71
100	2	9	17	25	35	45	56	67	80

TABLE 9

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 10 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	1	1	2	3
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	5	6	8	10
20	0	0	2	3	5	7	9	12	14
25	0	1	3	5	7	9	12	15	19
30	0	1	4	6	9	12	15	19	23
35	0	2	5	8	11	14	18	22	27
40	0	3	6	9	13	17	21	26	31
45	1	3	7	11	15	19	24	29	35
50	1	4	8	12	17	22	27	33	40
60	1	5	10	15	21	27	34	40	48
70	2	7	12	19	25	32	40	48	57
80	2	8	15	22	30	38	46	55	65
90	3	10	17	25	34	43	53	63	74
100	4	11	20	29	38	49	59	70	83

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	10	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	7	10	14	17	22
35	0	1	4	6	9	13	17	21	26
40	0	2	4	8	11	15	20	24	30
45	0	2	5	9	13	18	23	28	34
50	0	3	7	11	15	20	26	32	38
60	1	4	9	14	19	25	32	39	47
70	1	5	11	17	23	30	38	46	55
80	2	7	13	20	28	36	44	53	64
90	2	8	15	23	32	41	50	61	72
100	3	10	18	27	36	46	57	68	81

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	1	1	3	4	6	8	10
20	0	0	1	3	4	6	8	11	14
25	0	1	2	4	6	9	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	2	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	31
45	0	3	6	10	14	18	23	29	35
50	0	3	7	11	16	21	26	32	39
60	1	5	9	15	20	26	33	40	47
70	1	6	12	18	24	31	39	47	56
80	2	7	14	21	29	37	45	54	64
90	3	9	16	24	33	42	52	62	73
100	3	10	19	28	37	47	58	69	82

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	3	5	7	10	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	1	4	7	10	14	19	24	29
45	0	2	5	8	12	17	22	27	33
50	0	2	6	10	14	19	25	31	37
60	0	3	8	13	18	24	31	38	46
70	1	5	10	16	22	29	37	45	54
80	1	6	12	19	26	34	43	52	63
90	2	7	14	22	30	39	49	60	71
100	2	9	17	25	35	45	55	67	80

TABLE 10

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 11 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	2	3
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	5	6	8	10
20	0	0	2	3	5	7	9	11	14
25	0	1	3	5	7	9	12	15	19
30	0	1	4	6	9	12	15	19	23
35	0	2	5	7	11	14	18	22	27
40	0	3	6	9	13	17	21	26	31
45	1	3	7	11	15	19	24	29	35
50	1	4	8	12	17	22	27	33	40
60	1	5	10	15	21	27	33	40	48
70	2	7	12	19	25	32	40	48	57
80	2	8	15	22	30	38	46	55	65
90	3	10	17	25	34	43	53	63	74
100	4	11	20	29	38	48	59	70	82

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	10	13
25	0	0	2	3	6	8	11	14	18
30	0	1	3	5	7	10	14	17	22
35	0	1	3	6	9	13	16	21	26
40	0	2	4	8	11	15	19	24	30
45	0	2	5	9	13	18	22	28	34
50	0	3	6	11	15	20	25	31	38
60	1	4	9	14	19	25	32	39	47
70	1	5	11	17	23	30	38	46	55
80	2	7	13	20	27	35	44	53	64
90	2	8	15	23	32	41	50	61	72
100	3	9	18	26	36	46	57	68	81

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	3	4	6	8	10
20	0	0	1	3	4	6	8	11	14
25	0	1	2	4	6	9	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	2	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	30
45	0	3	6	10	14	18	23	29	35
50	0	3	7	11	16	21	26	32	39
60	1	5	9	14	20	26	32	39	47
70	1	6	12	18	24	31	39	47	56
80	2	7	14	21	28	36	45	54	64
90	3	9	16	24	33	42	51	62	73
100	3	10	19	28	37	47	58	69	82

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	3	5	7	10	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	7	10	13	17	21
35	0	1	3	5	8	12	16	20	25
40	0	1	4	7	10	14	19	23	29
45	0	2	5	8	12	17	22	27	33
50	0	2	6	10	14	19	24	30	37
60	0	3	8	13	18	24	31	38	46
70	1	5	10	16	22	29	37	45	54
80	1	6	12	19	26	34	43	52	63
90	2	7	14	22	30	39	49	59	71
100	2	9	16	25	35	45	55	67	80

TABLE 11

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 12 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	2	3
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	4	6	8	10
20	0	0	2	3	5	7	9	11	14
25	0	1	2	4	7	9	12	15	18
30	0	1	3	6	9	12	15	18	23
35	0	2	4	7	11	14	18	22	27
40	0	3	6	9	13	17	21	26	31
45	1	3	7	10	15	19	24	29	35
50	1	4	8	12	17	22	27	33	39
60	1	5	10	15	21	27	33	40	48
70	2	7	12	18	25	32	40	48	56
80	2	8	15	22	29	37	46	55	65
90	3	10	17	25	34	43	52	63	74
100	4	11	19	29	38	48	59	70	82

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	9
20	0	0	1	2	4	6	8	10	13
25	0	0	2	3	6	8	11	14	17
30	0	1	2	5	7	10	13	17	22
35	0	1	3	6	9	13	16	21	26
40	0	2	4	8	11	15	19	24	30
45	0	2	5	9	13	17	22	28	34
50	0	3	6	10	15	20	25	31	38
60	1	4	8	14	19	25	31	39	47
70	1	5	11	17	23	30	38	46	55
80	1	7	13	20	27	35	44	53	63
90	2	8	15	23	32	41	50	61	72
100	3	9	17	26	36	46	56	68	81

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	3	4	6	8	10
20	0	0	1	3	4	6	8	11	14
25	0	1	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	2	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	30
45	0	3	6	10	14	18	23	28	35
50	0	3	7	11	16	21	26	32	39
60	1	5	9	14	20	26	32	39	47
70	1	6	11	17	24	31	39	47	56
80	2	7	14	21	28	36	45	54	64
90	2	9	16	24	33	42	51	62	73
100	3	10	18	27	37	47	58	69	81

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	3	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	3	5	7	10	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	7	9	13	16	21
35	0	1	3	5	8	12	16	20	25
40	0	1	4	7	10	14	18	23	29
45	0	2	5	8	12	17	21	27	33
50	0	2	6	10	14	19	24	30	37
60	0	3	8	13	18	24	30	38	46
70	1	5	10	16	22	29	36	45	54
80	1	6	12	19	26	34	43	52	63
90	1	7	14	22	30	39	49	59	71
100	2	8	16	25	34	44	55	67	80

TABLE 12

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 13 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

STANDARD PROPORTION

NUMBER OF OBSERVATIONS (N)	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	2	2
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	4	6	8	10
20	0	0	2	3	5	7	9	11	14
25	0	1	2	4	7	9	12	15	18
30	0	1	3	6	9	11	15	18	23
35	0	2	4	7	10	14	18	22	27
40	0	3	5	9	12	16	21	26	31
45	0	3	7	10	15	19	24	29	35
50	1	4	8	12	17	22	27	33	39
60	1	5	10	15	21	27	33	40	48
70	2	7	12	18	25	32	40	48	56
80	2	8	15	22	29	37	46	55	65
90	3	9	17	25	34	43	52	62	74
100	4	11	19	28	38	48	59	70	82

P* = .975

STANDARD PROPORTION

NUMBER OF OBSERVATIONS (N)	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	9
20	0	0	1	2	4	6	8	10	13
25	0	0	2	3	5	8	11	14	17
30	0	1	2	5	7	10	13	17	21
35	0	1	3	6	9	13	16	21	26
40	0	2	4	7	11	15	19	24	30
45	0	2	5	9	13	17	22	28	34
50	0	3	6	10	15	20	25	31	38
60	1	4	8	13	19	25	31	38	46
70	1	5	11	17	23	30	38	46	55
80	1	7	13	20	27	35	44	53	63
90	2	8	15	23	31	40	50	60	72
100	3	9	17	26	36	46	56	68	80

P* = .950

STANDARD PROPORTION

NUMBER OF OBSERVATIONS (N)	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	3	4	6	7	10
20	0	0	1	3	4	6	8	11	14
25	0	1	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	1	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	30
45	0	3	6	10	14	18	23	28	34
50	0	3	7	11	16	21	26	32	39
60	1	5	9	14	20	26	32	39	47
70	1	6	11	17	24	31	38	47	56
80	2	7	14	21	28	36	45	54	64
90	2	9	16	24	32	42	51	61	73
100	3	10	18	27	37	47	57	69	81

P* = .990

STANDARD PROPORTION

NUMBER OF OBSERVATIONS (N)	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	3	5
15	0	0	0	1	2	3	5	6	9
20	0	0	0	2	3	5	7	10	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	7	9	13	16	21
35	0	1	3	5	8	12	16	20	25
40	0	1	4	7	10	14	18	23	29
45	0	2	5	8	12	16	21	27	33
50	0	2	6	10	14	19	24	30	37
60	0	3	8	12	18	24	30	37	46
70	1	5	10	15	22	29	36	45	54
80	1	6	12	19	26	34	43	52	62
90	1	7	14	22	30	39	49	59	71
100	2	8	16	25	34	44	55	67	79

TABLE 13

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 14 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	2	2
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	5	7	9	11	14
25	0	1	2	4	7	9	12	15	18
30	0	1	3	6	8	11	15	18	22
35	0	2	4	7	10	14	18	22	27
40	0	2	5	9	12	16	21	25	31
45	0	3	6	10	14	19	24	29	35
50	1	4	8	12	16	21	27	33	39
60	1	5	10	15	21	27	33	40	48
70	2	6	12	18	25	32	39	47	56
80	2	8	14	22	29	37	46	55	65
90	3	9	17	25	34	43	52	62	73
100	3	11	19	28	38	48	59	70	82

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	4	6	8	10	13
25	0	0	2	3	5	8	11	14	17
30	0	1	2	5	7	10	13	17	21
35	0	1	3	6	9	12	16	21	26
40	0	2	4	7	11	15	19	24	30
45	0	2	5	9	13	17	22	28	34
50	0	3	6	10	15	20	25	31	38
60	1	4	8	13	19	25	31	38	46
70	1	5	10	16	23	30	37	46	55
80	1	6	13	20	27	35	44	53	63
90	2	8	15	23	31	40	50	60	72
100	2	9	17	26	36	46	56	68	80

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	6	7	10
20	0	0	1	3	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	1	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	30
45	0	3	6	10	14	18	23	28	34
50	0	3	7	11	16	21	26	32	39
60	1	4	9	14	20	26	32	39	47
70	1	6	11	17	24	31	38	46	56
80	2	7	14	21	28	36	45	54	64
90	2	9	16	24	32	41	51	61	73
100	3	10	18	27	37	47	57	69	81

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	3	5
15	0	0	0	1	2	3	5	6	9
20	0	0	0	2	3	5	7	10	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	7	9	13	16	21
35	0	1	3	5	8	12	15	20	25
40	0	1	4	7	10	14	18	23	29
45	0	2	5	8	12	16	21	27	33
50	0	2	5	9	14	19	24	30	37
60	0	3	7	12	18	24	30	37	46
70	1	4	10	15	22	29	36	45	54
80	1	6	12	18	26	34	42	52	62
90	1	7	14	22	30	39	49	59	71
100	2	8	16	25	34	44	55	66	79

TABLE 14

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 15 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	2	2
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	5	7	9	11	14
25	0	1	2	4	6	9	12	15	18
30	0	1	3	6	8	11	15	18	22
35	0	2	4	7	10	14	18	22	27
40	0	2	5	9	12	16	21	25	31
45	0	3	6	10	14	19	24	29	35
50	1	4	7	12	16	21	27	33	39
60	1	5	10	15	21	27	33	40	48
70	2	6	12	18	25	32	39	47	56
80	2	8	14	21	29	37	46	55	65
90	3	9	17	25	33	42	52	62	73
100	3	11	19	28	38	48	58	70	82

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	4	6	8	10	13
25	0	0	2	3	5	8	10	14	17
30	0	1	2	5	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	2	4	7	11	15	19	24	30
45	0	2	5	9	13	17	22	28	34
50	0	3	6	10	15	20	25	31	38
60	0	4	8	13	19	25	31	38	46
70	1	5	10	16	23	30	37	46	55
80	1	6	13	20	27	35	44	53	63
90	2	8	15	23	31	40	50	60	72
100	2	9	17	26	35	45	56	68	80

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	1	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	30
45	0	3	6	9	14	18	23	28	34
50	0	3	7	11	16	21	26	32	39
60	1	4	9	14	20	26	32	39	47
70	1	6	11	17	24	31	38	46	55
80	2	7	13	20	28	36	45	54	64
90	2	8	16	24	32	41	51	61	73
100	3	10	18	27	37	47	57	69	81

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	3	5
15	0	0	0	1	2	3	4	6	9
20	0	0	0	2	3	5	7	10	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	6	9	13	16	21
35	0	1	3	5	8	12	15	20	25
40	0	1	4	7	10	14	18	23	29
45	0	2	4	8	12	16	21	27	33
50	0	2	5	9	14	19	24	30	37
60	0	3	7	12	18	24	30	37	46
70	1	4	10	15	22	29	36	44	54
80	1	6	12	18	26	34	42	52	62
90	1	7	14	22	30	39	49	59	71
100	2	8	16	25	34	44	55	66	79

TABLE 15

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 16 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	1	1	2	3	5	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	5	7	9	11	14
25	0	1	2	4	6	9	12	15	18
30	0	1	3	6	8	11	15	18	22
35	0	2	4	7	10	14	18	22	27
40	0	2	5	9	12	16	21	25	31
45	0	3	6	10	14	19	24	29	35
50	1	4	7	12	16	21	27	33	39
60	1	5	10	15	20	26	33	40	48
70	2	6	12	18	25	32	39	47	56
80	2	8	14	21	29	37	46	55	65
90	3	9	17	25	33	42	52	62	73
100	3	11	19	28	38	48	58	70	82

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	4	5	8	10	13
25	0	0	2	3	5	8	10	14	17
30	0	1	2	5	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	2	4	7	11	15	19	24	30
45	0	2	5	9	13	17	22	27	34
50	0	3	6	10	15	20	25	31	38
60	0	4	8	13	19	25	31	38	46
70	1	5	10	16	23	30	37	45	55
80	1	6	13	19	27	35	43	53	63
90	2	8	15	23	31	40	50	60	72
100	2	9	17	26	35	45	56	68	80

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	1	4	6	10	13	17	21	26
40	0	2	5	8	11	15	20	25	30
45	0	2	6	9	13	18	23	28	34
50	0	3	7	11	15	20	26	32	38
60	1	4	9	14	20	26	32	39	47
70	1	6	11	17	24	31	38	46	55
80	2	7	13	20	28	36	44	54	64
90	2	8	16	24	32	41	51	61	72
100	3	10	18	27	36	47	57	69	81

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	3	5
15	0	0	0	1	2	3	4	6	9
20	0	0	0	2	3	5	7	10	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	6	9	13	16	21
35	0	1	3	5	8	12	15	20	25
40	0	1	4	7	10	14	18	23	29
45	0	2	4	8	12	16	21	27	33
50	0	2	5	9	14	19	24	30	37
60	0	3	7	12	18	24	30	37	45
70	1	4	9	15	22	29	36	44	54
80	1	6	12	18	26	34	42	52	62
90	1	7	14	21	30	39	48	59	71
100	2	8	16	25	34	44	55	66	79

TABLE 16

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 17 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	1	1	2	3	4	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	5	6	9	11	14
25	0	1	2	4	6	9	12	15	18
30	0	1	3	6	8	11	14	18	22
35	0	2	4	7	10	14	17	22	26
40	0	2	5	9	12	16	20	25	31
45	0	3	6	10	14	19	24	29	35
50	1	4	7	12	16	21	27	32	39
60	1	5	10	15	20	26	33	40	48
70	2	6	12	18	25	32	39	47	56
80	2	8	14	21	29	37	45	55	65
90	3	9	17	25	33	42	52	62	73
100	3	11	19	28	38	48	58	70	82

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	4	5	8	10	13
25	0	0	1	3	5	8	10	13	17
30	0	1	2	4	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	2	4	7	11	15	19	24	30
45	0	2	5	9	13	17	22	27	34
50	0	3	6	10	15	20	25	31	38
60	0	4	8	13	19	25	31	38	46
70	1	5	10	16	23	30	37	45	55
80	1	6	12	19	27	35	43	53	63
90	2	8	15	23	31	40	50	60	72
100	2	9	17	26	35	45	56	67	80

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	11	14	17	22
35	0	1	4	6	10	13	17	21	26
40	0	2	5	8	11	15	20	25	30
45	0	2	6	9	13	18	23	28	34
50	0	3	7	11	15	20	26	32	38
60	1	4	9	14	19	25	32	39	47
70	1	6	11	17	24	31	38	46	55
80	2	7	13	20	28	36	44	54	64
90	2	8	16	24	32	41	51	61	72
100	3	10	18	27	36	46	57	68	81

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	3	5
15	0	0	0	1	2	3	4	6	9
20	0	0	0	2	3	5	7	10	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	6	9	12	16	21
35	0	1	3	5	8	11	15	20	25
40	0	1	3	6	10	14	18	23	29
45	0	2	4	8	12	16	21	27	33
50	0	2	5	9	14	19	24	30	37
60	0	3	7	12	18	24	30	37	45
70	0	4	9	15	22	29	36	44	54
80	1	6	12	18	26	34	42	52	62
90	1	7	14	21	30	39	48	59	71
100	2	8	16	25	34	44	55	66	79

TABLE 17

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 18 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	4	6	9	11	14
25	0	1	2	4	6	9	11	15	18
30	0	1	3	6	8	11	14	18	22
35	0	2	4	7	10	14	17	22	26
40	0	2	5	8	12	16	20	25	31
45	0	3	6	10	14	19	23	29	35
50	1	4	7	12	16	21	27	32	39
60	1	5	9	15	20	26	33	40	48
70	2	6	12	18	25	32	39	47	56
80	2	8	14	21	29	37	45	55	65
90	3	9	16	25	33	42	52	62	73
100	3	11	19	28	37	48	58	69	82

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	4	5	8	10	13
25	0	0	1	3	5	8	10	13	17
30	0	1	2	4	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	1	4	7	11	15	19	24	29
45	0	2	5	9	13	17	22	27	34
50	0	3	6	10	15	20	25	31	38
60	0	4	8	13	19	25	31	38	46
70	1	5	10	16	23	30	37	45	55
80	1	6	12	19	27	35	43	53	63
90	2	8	15	22	31	40	50	60	72
100	2	9	17	26	35	45	56	67	80

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	10	14	17	22
35	0	1	4	6	9	13	17	21	26
40	0	2	5	8	11	15	20	24	30
45	0	2	6	9	13	18	23	28	34
50	0	3	7	11	15	20	26	32	38
60	1	4	9	14	19	25	32	39	47
70	1	6	11	17	24	31	38	46	55
80	2	7	13	20	28	36	44	54	64
90	2	8	16	23	32	41	51	61	72
100	3	10	18	27	36	46	57	68	81

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	3	5
15	0	0	0	1	2	3	4	6	9
20	0	0	0	2	3	5	7	9	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	6	9	12	16	21
35	0	1	3	5	8	11	15	20	25
40	0	1	3	6	10	14	18	23	29
45	0	2	4	8	12	16	21	26	33
50	0	2	5	9	14	19	24	30	37
60	0	3	7	12	18	23	30	37	45
70	0	4	9	15	22	28	36	44	54
80	1	6	11	18	26	34	42	52	62
90	1	7	14	21	30	39	48	59	71
100	2	8	16	24	34	44	55	66	79

TABLE 18

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 19 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	4	6	9	11	14
25	0	1	2	4	6	9	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	2	4	7	10	14	17	22	26
40	0	2	5	8	12	16	20	25	31
45	0	3	6	10	14	19	23	29	35
50	1	3	7	11	16	21	26	32	39
60	1	5	9	15	20	26	33	40	47
70	2	6	12	18	24	31	39	47	56
80	2	8	14	21	29	37	45	54	65
90	3	9	16	24	33	42	52	62	73
100	3	10	19	28	37	47	58	69	82

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	4	5	8	10	13
25	0	0	1	3	5	8	10	13	17
30	0	1	2	4	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	1	4	7	11	15	19	24	29
45	0	2	5	9	13	17	22	27	34
50	0	3	6	10	15	19	25	31	38
60	0	4	8	13	18	24	31	38	46
70	1	5	10	16	23	30	37	45	55
80	1	6	12	19	27	35	43	53	63
90	2	8	15	22	31	40	50	60	72
100	2	9	17	26	35	45	56	67	80

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	11	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	8	10	14	17	22
35	0	1	4	6	9	13	17	21	26
40	0	2	5	8	11	15	20	24	30
45	0	2	6	9	13	18	23	28	34
50	0	3	7	11	15	20	26	32	38
60	1	4	9	14	19	25	32	39	47
70	1	5	11	17	23	30	38	46	55
80	2	7	13	20	28	36	44	53	64
90	2	8	15	23	32	41	51	61	72
100	3	10	18	27	36	46	57	68	81

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	3	5
15	0	0	0	1	2	3	4	6	9
20	0	0	0	2	3	5	7	9	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	6	9	12	16	21
35	0	1	3	5	8	11	15	20	25
40	0	1	3	6	10	14	18	23	29
45	0	1	4	8	12	16	21	26	33
50	0	2	5	9	14	19	24	30	37
60	0	3	7	12	17	23	30	37	45
70	0	4	9	15	21	28	36	44	54
80	1	5	11	18	26	33	42	51	62
90	1	7	14	21	30	39	48	59	71
100	2	8	16	24	34	44	54	66	79

TABLE 19

VALUES OF M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF
K = 20 BINOMIAL POPULATIONS WHICH CONTAINS
ALL POPULATIONS BETTER THAN A STANDARD
(POPULATIONS WITH NO. OF 'SUCCESSES' >= M ARE SELECTED)

P* = .900

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	1	2	3	4	6	8	10
20	0	0	1	3	4	6	9	11	14
25	0	1	2	4	6	9	11	14	18
30	0	1	3	5	8	11	14	18	22
35	0	2	4	7	10	13	17	21	26
40	0	2	5	8	12	16	20	25	31
45	0	3	6	10	14	18	23	29	35
50	1	3	7	11	16	21	26	32	39
60	1	5	9	15	20	26	33	40	47
70	1	6	12	18	24	31	39	47	56
80	2	7	14	21	29	37	45	54	64
90	3	9	16	24	33	42	52	62	73
100	3	10	19	28	37	47	58	69	82

P* = .975

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	1	2	4	5
15	0	0	0	1	2	3	5	7	9
20	0	0	1	2	3	5	7	10	13
25	0	0	1	3	5	8	10	13	17
30	0	1	2	4	7	10	13	17	21
35	0	1	3	6	9	12	16	20	25
40	0	1	4	7	11	15	19	24	29
45	0	2	5	9	13	17	22	27	34
50	0	2	6	10	14	19	25	31	38
60	0	4	8	13	18	24	31	38	46
70	1	5	10	16	22	29	37	45	54
80	1	6	12	19	27	35	43	53	63
90	2	8	15	22	31	40	49	60	71
100	2	9	17	26	35	45	56	67	80

P* = .950

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	1	1	2
10	0	0	0	0	1	2	3	4	6
15	0	0	0	1	2	4	5	7	10
20	0	0	1	2	4	6	8	10	14
25	0	0	2	4	6	8	11	14	18
30	0	1	3	5	7	10	14	17	22
35	0	1	4	6	9	13	17	21	26
40	0	2	5	8	11	15	20	24	30
45	0	2	5	9	13	18	23	28	34
50	0	3	7	11	15	20	26	32	38
60	1	4	9	14	19	25	32	39	47
70	1	5	11	17	23	30	38	46	55
80	2	7	13	20	28	36	44	53	64
90	2	8	15	23	32	41	50	61	72
100	3	10	18	27	36	46	57	68	81

P* = .990

NUMBER OF OBSERVATIONS (N)	STANDARD PROPORTION .1	.2	.3	.4	.5	.6	.7	.8	.9
5	0	0	0	0	0	0	0	1	2
10	0	0	0	0	0	1	2	3	5
15	0	0	0	1	2	3	4	6	9
20	0	0	0	1	3	5	7	9	13
25	0	0	1	3	5	7	10	13	17
30	0	0	2	4	6	9	12	16	21
35	0	1	3	5	8	11	15	19	25
40	0	1	3	6	10	14	18	23	29
45	0	1	4	8	12	16	21	26	33
50	0	2	5	9	14	18	24	30	37
60	0	3	7	12	17	23	30	37	45
70	0	4	9	15	21	28	36	44	54
80	1	5	11	18	25	33	42	51	62
90	1	7	14	21	30	39	48	59	71
100	2	8	16	24	34	44	54	66	79

Table 20

Quantity h needed for selecting, with probability of correct selection at least P*, from k populations the population with the smallest mean (nl = 30)

P* \ k	2	3	4	5	6	7	8	9	10	11	12	13
.75	0.98	1.47	1.73	1.90	2.03	2.13	2.21	2.28	2.35	2.40	2.45	2.49
.80	1.22	1.70	1.95	2.12	2.24	2.34	2.42	2.49	2.55	2.61	2.66	2.70
.85	1.51	1.96	2.21	2.37	2.49	2.59	2.67	2.74	2.80	2.85	2.90	2.94
.90	1.87	2.30	2.54	2.69	2.81	2.91	2.98	3.05	3.11	3.16	3.21	3.25
.95	2.41	2.81	3.03	3.18	3.30	3.39	3.46	3.53	3.18	3.63	3.68	3.72
.975	2.88	3.27	3.48	3.62	3.73	3.82	3.89	3.95	4.01	4.05	4.10	4.14
.99	3.45	3.81	4.01	4.14	4.25	4.33	4.40	4.46	4.51	4.56	4.60	4.64

P* \ k	14	15	16	17	18	19	20	21	22	23	24	25
.75	2.53	2.57	2.60	2.63	2.66	2.69	2.72	2.74	2.76	2.78	2.81	2.83
.80	2.74	2.77	2.81	2.84	2.87	2.89	2.92	2.94	2.96	2.99	3.01	3.03
.85	2.98	3.01	3.05	3.08	3.10	3.13	3.16	3.18	3.20	3.20	3.24	3.26
.90	3.29	3.32	3.35	3.38	3.41	3.44	3.46	3.48	3.51	3.53	3.55	3.57
.95	3.75	3.79	3.82	3.85	3.87	3.90	3.92	3.95	3.97	3.99	4.01	4.03
.975	4.17	4.20	4.24	4.27	4.29	4.32	4.34	4.36	4.38	4.40	4.42	4.44
.99	4.68	4.71	4.74	4.76	4.79	4.81	4.84	4.86	4.88	4.90	4.92	4.94

Table 21

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k populations the one with the largest .5-quantile

d* = .20

P* \ k	2	3	4	5	6	7	8	9	10
.550	1	3	7	9	11	11	13	15	15
.600	3	5	9	11	13	15	15	17	19
.650	5	7	11	13	15	17	19	21	23
.700	5	9	13	17	19	21	23	25	27
.750	9	13	17	21	23	25	27	29	31
.800	11	17	21	25	29	31	33	35	37
.850	15	23	29	33	35	39	41	43	45
.900	21	31	37	41	45	47	51	53	55
.950	35	45	51	57	61	65	67	69	71
.975	47	59	67	73	77	81	83	87	89
.990	67	79	89	93	99	103	105	107	111

Table 22

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k populations the one with the largest .5-quantile

d* = .15

P* \ k	2	3	4	5	6	7	8	9	10
.550	3	7	11	15	19	21	23	27	29
.600	5	11	15	19	23	27	29	31	33
.650	7	13	19	25	29	31	35	37	41
.700	11	19	25	31	35	39	41	45	47
.750	15	23	31	37	43	47	51	53	55
.800	19	31	39	47	51	57	59	63	67
.850	27	41	51	57	63	69	73	77	79
.900	39	55	67	75	81	85	91	95	97
.950	61	81	93	103	109	115	121	125	129
.975	85	107	121	131	139	145	149	155	159
.990	119	143	159	169	177	189	189	193	197

Table 23

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k populations the one with the largest .5-quantile

d* = .10

P* \ k	2	3	4	5	6	7	8	9	10
.550	9	17	27	35	43	49	55	61	65
.600	11	23	35	45	53	61	67	73	77
.650	17	31	45	55	65	73	79	87	91
.700	23	41	57	69	79	87	95	103	107
.750	33	53	71	85	97	105	113	121	127
.800	45	71	89	105	117	127	135	143	151
.850	63	93	115	131	145	155	165	173	179
.900	89	125	149	169	183	195	205	213	221
.950	139	183	211	233	249	261	273	281	291
.975	195	243	275	297	313	327	339	349	359
.990	271	325	359	383	401	415	427	439	449

Table 24

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k populations the one with the largest .5-quantile

d* = .10

P* \ k	2	3	4	5	6	7	8	9	10
.550	31	69	107	141	171	197	221	243	263
.600	47	93	139	179	213	243	269	291	313
.650	67	125	179	223	261	293	323	347	369
.700	95	165	227	277	319	353	385	411	435
.750	131	217	285	341	387	425	457	487	511
.800	181	283	361	421	471	511	547	577	605
.850	253	371	459	527	579	623	661	695	723
.900	361	503	601	675	733	781	823	857	889
.950	563	737	851	933	997	1049	1095	1133	1167
.975	781	979	1103	1191	1259	1317	1363	1405	1441
.990	1087	1307	1439	1535	1607	1667	1717	1761	1801

Table 25[+]

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k populations the one with the largest .9-quantile

d* = .04

P* \ k	2	3	4	5	6	7	8	9	10
.550	19	59	99	129	159	179	199	209	229
.600	19	79	119	149	179	199	219	239	249
.650	29	99	139	179	199	229	249	269	279
.700	49	119	169	209	239	259	279	299	309
.750	69	149	199	239	269	299	319	339	349
.800	99	189	239	279	319	339	359	379	399
.850	139	239	299	339	369	399	419	449	459
.900	209	309	369	419	459	479	509	529	549
.950	329	439	409	559	599	629	659	679	699
.975	449	569	649	699	739	779	809	829	849
.990	619	759	829	889	929	969	999	1029	1049

[+]The values in this table were computed by Professor Edward J. Dudewicz and Mr. Ishwari Dutt Dharigal under the auspices of the Statistics Laboratory at The Ohio State University.

Table 26[+]

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k populations the one with the largest .9-quantile

$d^* = .025$

P* \ k	2	3	4	5	6	7	8	9	10
.550	39	149	249	319	379	429	479	519	549
.600	59	189	299	379	439	489	539	579	609
.650	89	239	349	439	499	559	609	639	689
.700	129	299	419	509	579	639	689	729	769
.750	189	379	499	599	669	729	779	829	869
.800	259	469	609	699	779	849	899	949	989
.850	369	599	739	849	929	999	1049	1099	1149
.900	529	779	939	1049	1139	1209	1269	1319	1369
.950	819	1109	1279	1399	1499	1579	1649	1699	1759
.975	1139	1449	1629	1759	1869	1949			
.990	1579	1909							

[+]The values in this table were computed by Professor Edward J. Dudewicz and Mr. Ishwari Dutt Dharigal under the auspices of the Statistics Laboratory at The Ohio State University. The missing values are all greater than 2000.

Table 27

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k Binomial populations the one with largest proportion

k = 2

d* \ P*	0.60	0.75	0.80	0.85	0.90	0.95	0.99
0.05	14	92	142	215	329	541	1082
0.10	4	23	36	54	83	135	270
0.15	2	11	16	24	37	60	120
0.20	1	6	9	14	21	34	67
0.25	1	4	6	9	14	22	42
0.30	1	3	4	6	9	15	29
0.35	1	2	3	5	7	11	21
0.40	1	2	3	4	5	9	16
0.45	1	2	2	3	4	7	13
0.50	1	1	2	3	4	5	10

Table 28

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k Binomial populations the one with largest proportion

k = 3

d* \ P*	0.50	0.60	0.75	0.80	0.85	0.90	0.95	0.99
0.05	31	79	206	273	364	498	735	1308
0.10	8	20	52	69	91	125	184	327
0.15	4	9	23	31	41	55	82	145
0.20	3	5	13	17	23	31	46	81
0.25	2	4	9	11	15	20	29	52
0.30	2	3	6	8	10	14	20	35
0.35	2	2	5	6	8	10	15	26
0.40	1	2	4	5	6	8	11	20
0.45	1	2	3	4	5	6	9	15
0.50	1	2	3	3	4	5	7	12

Table 29

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k Binomial populations the one with largest proportion

k = 4

d* \ P*	0.50	0.60	0.75	0.80	0.85	0.90	0.95	0.99
0.05	71	134	283	359	458	601	850	1442
0.10	18	34	71	90	114	150	212	360
0.15	8	15	32	40	51	67	94	160
0.20	5	9	18	23	29	38	53	89
0.25	3	6	12	14	18	24	34	57
0.30	3	4	8	10	13	17	23	39
0.35	2	3	6	7	9	12	17	28
0.40	2	3	5	6	7	9	13	21
0.45	2	2	4	5	6	7	10	17
0.50	2	2	3	4	5	6	8	13

Table 30

Number n of observations required per population for selecting, with probability of correct selection at least P*, from k Binomial populations the one with largest proportion

k = 10

d* \ P*	0.50	0.60	0.75	0.80	0.85	0.90	0.95	0.99
0.05	218	314	513	606	725	890	1169	1803
0.10	55	79	128	151	181	222	291	449
0.15	25	35	57	67	80	98	129	198
0.20	14	20	32	38	45	55	72	111
0.25	9	13	20	24	29	35	46	70
0.30	7	9	14	17	20	24	32	48
0.35	5	7	11	13	15	18	23	35
0.40	4	5	8	10	11	13	17	26
0.45	3	4	6	8	9	11	14	20
0.50	3	4	5	6	7	9	11	16

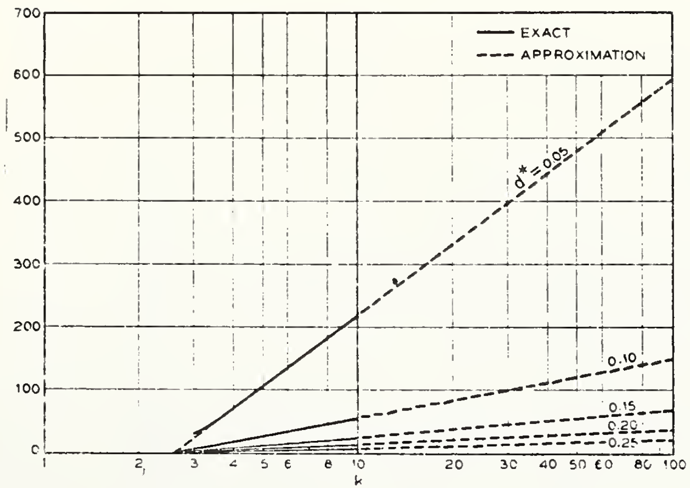

Figure 1 Number n of observations required per population for selecting, with probability of correct selection at least P*=.50, from k binomial populations the one with largest proportion.

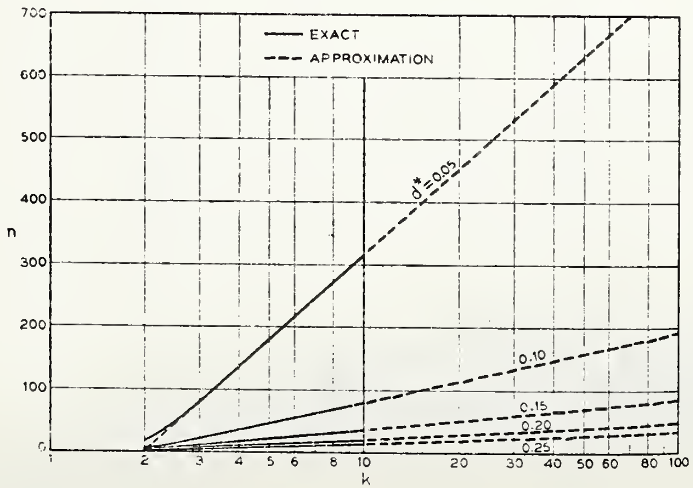

Figure 2 Number n of observations required per population for selecting, with probability of correct selection at least P*=.60, from k binomial populations the one with largest proportion.

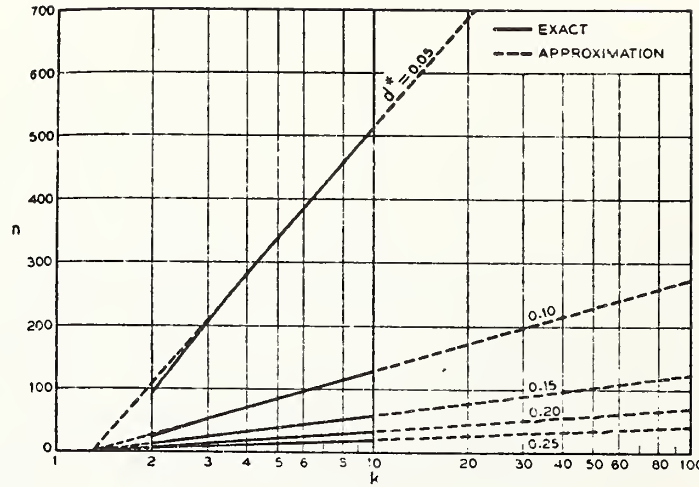

Figure 3 Number n of observations required per population for selecting, with probability of cor - rect selection at least P*=.75, from k binomial populations the one with largest proportion.

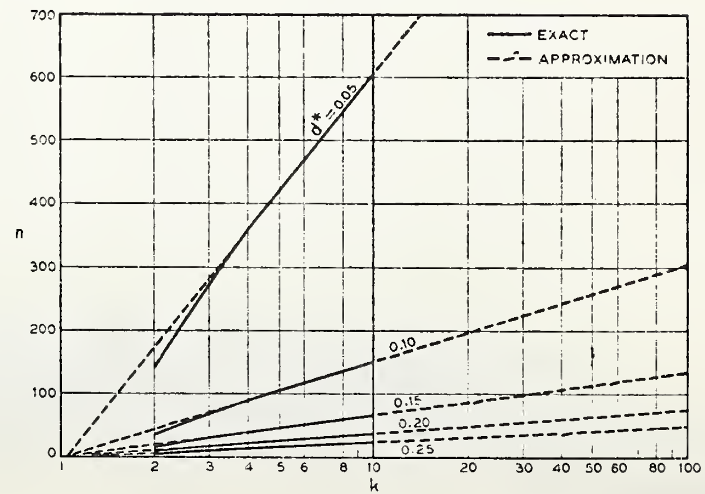

Figure 4 Number n of observations required per population for selecting, with probability of cor - rect selection at least P*=.80, from k binomial populations the one with largest proportion.

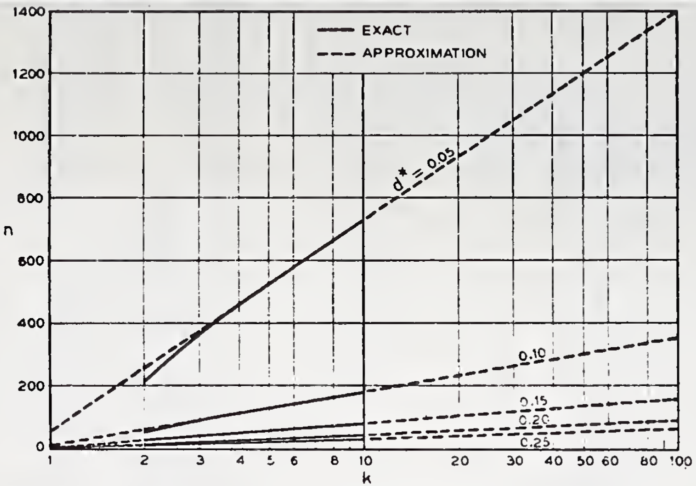

Figure 5 Number n of observations required per population for selecting, with probability of correct selection at least P*=.85, from k binomial populations the one with largest proportion.

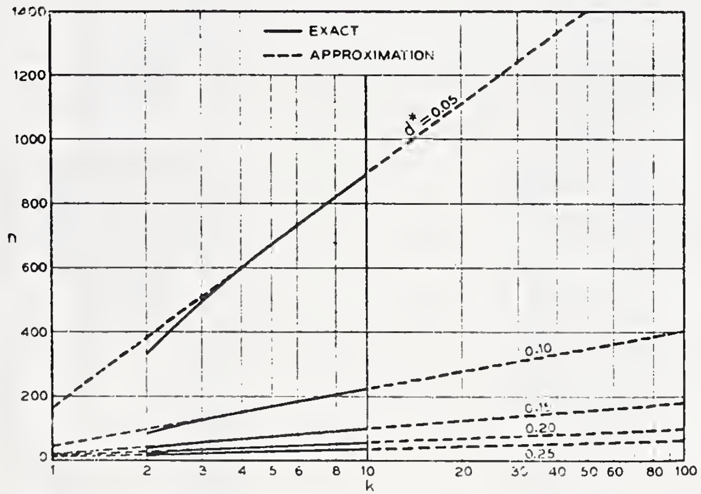

Figure 6 Number n of observations required per population for selecting, with probability of correct selection at least P*=.90, from k binomial populations the one with largest proportion.

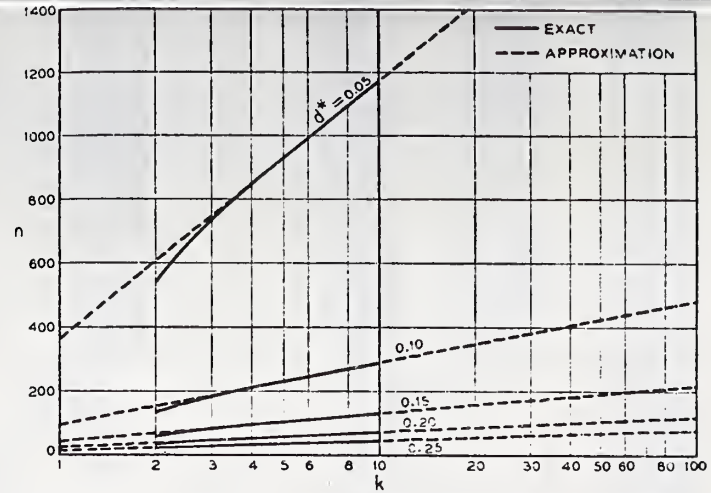

Figure 7 Number n of observations required per population for selecting, with probability of correct selection at least P*=.95, from k binomial populations the one with largest proportion.

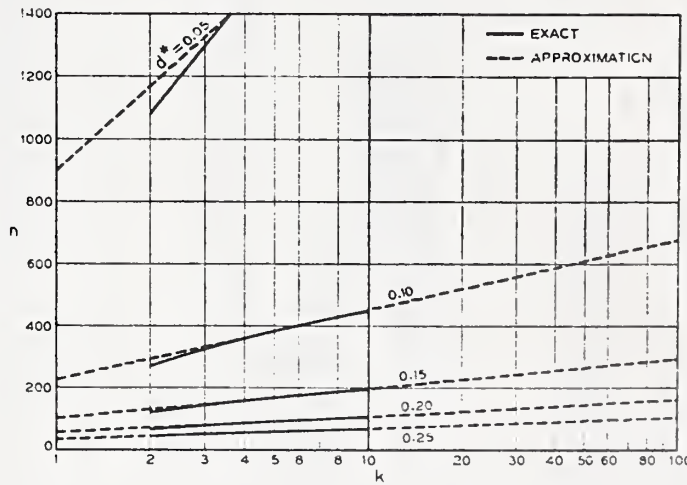

Figure 8 Number n of observations required per population for selecting, with probability of correct selection at least P*=.99, from k binomial populations the one with largest proportion.

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This publication addresses the comparison and selection of remote access interactive computer services. The comparison methodology presented relies principally on the statistical analysis of measurement data obtained from the interaction between a computer service and a user. One of the most important properties of the methodology is that it incorporates confidence statements about the probability of having made a correct selection. Experimental data are presented to illustrate an application of the methodology, and serve as a basis for a discussion of the cost and appropriateness of using the methodology in various procurement efforts.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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NOTE: At present the principal publication outlet for these data is the Journal of Physical and Chemical Reference Data (JPCRD) published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements available from ACS, 1155 Sixteenth St. N.W., Wash., D.C. 20056.

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