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CE & TECHNOLOGY:

Application of Measurement Criteria in the Selection of Interactive Computer Services



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NBS Special Publication 500-58

U.S. DEPARTMENT OF COMMERCE National Bureau of Standards

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COMPUTER SCIENCE & TECHNOLOGY:

Application of Measurement Criteria in the Selection of Interactive Computer Services

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DISCLAIMER

This publication discusses three procedures which may be utilized in the experimental design - data analysis components of a remote access computer service selection. It is not intended to represent the entire government computer service procurement process. Consideration of testing costs, bidding procedures, environment test conditions, and other selection issues are beyond the scope of this publication.



Application of Measurement Criteria in the Selection of Interactive Computer Services

Paul D. Amer

ABSTRACT

This publication emphasizes the data analysis component of the computer service selection process. A computer service selection model, introduced in NBS Special Publication 500-44, is presented and three binary type selection procedures applicable in the measurement phases of that model are given. A binary type procedure determines which competing computer services perform above and which perform below a specified performance level. Those services determined to perform below a specified performance level can be eliminated or penalized depending on whether the performance specification is mandatory or desirable. The procedures explicitly specify prior to measurement an appropriate decision rule and/or the number of test measurements required in a comparison effort to attain a given level of statistical confidence in the results. Experimental data from a previous case study are reanalyzed to illustrate application of the selection procedures. If the collection of measurements is necessary in a computer service selection, then these procedures (or similar statistically sound procedures) should be employed because of their mathematical justification.

Key words: Binary selection; computer comparison; computer performance measurement; computer service; data analysis; experimental design; performance evaluation; ranking and selection; selection methodology.

1.0 INTRODUCTION

NBS Special Publication 500-44 [MAM79a] (herein referred as SP 500-44) addresses the comparison and selection of remote access interactive computer services in terms of a statistical comparison methodology. That methodology relies principally on the collection and statistical analysis of measurement data obtained from the interactions between a computer service and a user. Four general test procedures or experimental designs are described for use in the data analysis component of the comparison and selection process.

Three of the procedures in SP 500-44 determine the "best" of a set of computer services where best is defined by a single performance index and either a mean, percentile or proportion statistic. For example, one of the procedures might be employed to determine the computer service with the shortest mean response time for all text-editor transactions.

The fourth procedure in SP 500-44 determines a subset of computer services that includes all services which, for a performance index, perform at or particular above а "single proportion" performance level. specified For example, the procedure will determine a subset of computer services that includes all services for which at least 80% of the response times are less than two seconds. This procedure is a "binary" or "yes-no" type procedure since for each service a decision is made either to include it in or to exclude it from the selected subset. A binary type procedure provides an analyst with reliable performance information about which services perform above and which services perform below a specified performance level.

This Special Publication also emphasizes the experimental design - data analysis components of the computer service selection process. Introduced are two binary type selection procedures which are extensions of the binary type procedure in SP 500-44. The first procedure determines a subset of computer services that includes all services which, for a particular performance index, perform at or above a specified "dual proportion" performance level. For example, the procedure will determine a of subset computer services that includes all services for which at least 50% of the response times are less than two seconds and at least 80% of the responses are less than five seconds. A dual proportion permits greater flexibility than single proportion in defining measurable performance by a specifying two, rather than one, statistical values of interest of each service's performance distribution.

The second procedure determines a subset of computer services that includes all services which, for a particular performance index, perform at or above a specified "upper proportion" performance level and excludes all services which perform at or below a specified "lower proportion" performance level. For example, suppose computer services

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are defined to be in one of three categories: (1) those with 80% or more responses less than two seconds, (2) those with 50%-80% responses less than two seconds, and (3) those with 50% or less responses less than two seconds. This procedure will determine a subset that includes all services in category (1) and excludes all services in category (3). An upper-lower proportion combination permits greater control than a single or dual proportion by regulating just how poorly a service can perform and still be selected due to variability present in a measurement study.

important characteristic of the procedures An in SP 500-44 and here is the analyst's ability to control (limit, bound) the probability of obtaining an incorrect selection (further explained in Section 3.2). These procedures explicitly specify prior to measurement an appropriate decision rule and/or the number of measurements required in a computer service comparison to attain a qiven level of statistical confidence in the results. Although each procedure compares services for a single performance index, together they may be employed for several indices with the individual results then integrated in a comprehensive selection methodology (see Section 2.3). The procedures specifically are applicable in a comparison effort whenever a selection methodology requires binary information about a set of competing computer services, i.e. which services do and which services do not provide a certain level of performance.

If the collection of measurements is necessary in a computer service selection, then these procedures (or similar statistically sound procedures) should be employed because their mathematical foundation permits an analyst to justify and document the selection making process.

2.0 SELECTION OF INTERACTIVE COMPUTER SERVICES

Federal Information Processing Guidelines for the Measurement of Remote Access Interactive Computer Service Response Time and Turnaround Time [FIP57] indicates that when two or more computer services are being compared, statistics and statistical techniques should be employed for the description and analysis of the measurements which are collected. Further, since the statistical techniques which are employed can influence the results, the techniques <u>must</u> be clearly specified in advance. With regard to the kind of statistics to employ, the guidelines more specifically state:

"Quite often the distributions of response time and turnaround time are not known (in closed the data mathematical form). Since most of distributions which have been collected and analyzed have been non-normal (non-Gaussian), Gaussian statistical descriptors such as the mean and standard deviation are not appropriate. It is therefore recommended that non-parametric statistical descriptors be employed when specifying response time and turnaround time."

Performance data in a computer service selection usually are collected in an uncontrolled environment. That is, an analyst exercises little or no control over the software, hardware or external 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, control of the technical aspects of how services are produced or how they are delivered when they purchase computer services (in contrast to computer systems) [ABR77b]. However, they do desire a guaranteed level of service at their terminal interface and that is precisely what is measured. Due to the many uncontrolled variables present in a typical computer service evaluation effort, there is an unknown degree of variability in the collected measurements. Therefore, it is necessary to employ valid statistical techniques and to collect multiple measurements to confidently obtain an accurate estimate of a computer service's performance. This publication addresses the questions of what data analysis technique and how many measurements are necessary for a desired level of statistical confidence in the comparison and selection results.

A computer service selection model (CSSM) is presented in SP 500-44. Based on that model, a methodology is given which relies principally on the statistical analysis of measurement data obtained from the interactions between a computer service and a user. The methodology incorporates

(+) Complete specification of the testing environment is beyond the scope of this publication.

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confidence statements about the probabilities of correct selections made at various phases of a computer service selection process. The technical and economic feasibilities of applying the selection methodology are verified in a case study comparing four heterogenous remote access time sharing services. (It is recommended that the reader study SP 500-44 for a global view of the selection process. Some portions of SP 500-44 have been summarized in this SP for completeness.)

This publication presents selection procedures beyond those previously published in SP 500-44 for use in the measurement phases of a computer service selection when the criteria for selection are measurable and are expressed in terms of proportion statistics. Specifically, they are applicable when the analyst wishes to know only if a service performs above or below a specified performance level.

One of the four experimental procedures that are presented in SP 500-44 (Section 2.4.1) is repeated here to assist the reader in understanding proportion criteria and to facilitate presentation of the two additional procedures that follow. In conjunction with SP 500-44, this publication furthers the development of a statistical methodology for the comparison and selection of interactive computer services.

2.1 Classification of Performance Criteria

The computer service comparison and selection process is a complicated one, based on various performance indices. Some indices are measurable (such as service response time), and some are not (such as ease of service use and coherence of service documentation). For example, evaluating service documentation and the amount of main memory does not require measurement collecting activity, whereas evaluating service turnaround time and response time clearly requires measurement. When criteria are based on measurable indices, comparison requires collecting and analyzing relevant performance measurements from the various computer services being considered.

Performance criteria can be divided further into those which are mandatory and those which are desirable. A mandatory criterion defines a service requirement which <u>must</u> be satisfied by the computer services being considered for selection. Failure to satisfy even one mandatory criterion results in a service's elimination. Desirable criteria, on the other hand, are those which are not absolute requirements for acceptance, but which if satisfied would facilitate processing of a user's workload. Therefore, if a given computer service does not fulfill some desirable criteria, it would continue to be considered for selection, but depending on the overall selection methodology failure to satisfy each desirable criterion would perhaps invoke some associated penalty on the respective service. (Likewise, for each desirable criterion satisfied, a given service could be compensated with an associated reward.)

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.

There are a large number of performance indices which may be used for defining comparison criteria in a computer service selection. Abrams and Treu [ABR77b] have tabulated more than fifty measures which may be used to describe the demands and needs of a user at an interactive terminal. Those measures which describe the time, length, rate and ratios of user-computer interactive behavior, are likely to be of primary interest in the evaluation and selection of computer services, especially the three measures of response time, turnaround time and cost.

Ultimately a decision about how many and which performance factors are most important in an evaluation is a management policy issue. One user may view system reliablility as the over-riding consideration in a service selection effort while another might view cost and response time for short edit commands as the most important factors. Usually some combination of various measures of service response time and costs is used in the selection process. <u>This publication makes no statement about which performance indices should be used in defining selection criteria</u>. It does, however, assume that selection criteria exist and can be stated in advance of any measurement effort.

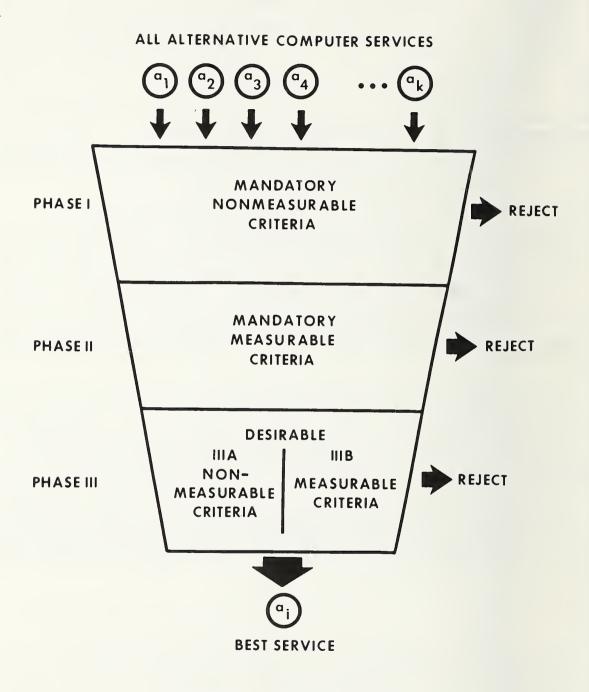
2.2 Application of Performance Criteria

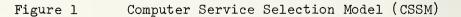
The CSSM in SP 500-44 indicates a sequence in which the four classes of performance criteria typically are applied in most service selection methodologies. This model is repeated here in Figure 1. Phase I involves the application of MN criteria. The phase is managed easily since each

Table 1

Examples of Performance Criteria

Туре	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 turnaround time for all student jobs must be less than 15 minutes.	
	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.	





computer service either does or does not have the required characteristic. All of those services 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. A typical selection criterion that might be applied in phase II is "consider only those services which provide a turnaround time of five minutes or less for at least 80% of the remote job entry requests."

Finally, determination of the best computer service 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 that it is not implied that DN and DM criteria are necessarily applied separately or in any particular order.) Phase III involves gathering both measurement and subjective data and integrating all of the information in a complex manner to determine which computer service is the best one. A service's failure to satisfy a desirable criterion results not in its elimination, but rather in a penalty to compensate it with those services that do satisfy the desirable criterion. Different selection methodologies incorporate these penalties into the overall selection process in different manners, yet the effect is the same. Typical questions asked in phase III are "does a service provide adequate software and hardware documentation?" and "does a service have a desired x% of its response times less than a five second threshold?".

In both phases II and IIIB, comparison requires collecting and analyzing relevant performance measurements from the various computer services under consideration: in phase II, to eliminate those services failing to satisfy mandatory performance requirements, and in phase IIIB, to penalize those services failing to perform at desirable performance levels.

2.3 Methodology for Selection

To understand better how the procedures described in Section 3 fit into the overall selection process, two general approaches to computer service selection are now discussed. The first approach applies a set of mandatory criteria and then chooses the least expensive service remaining. In terms of the CSSM, phase III is greatly simplified with this approach (since minimum cost becomes the only desirable criterion). When possible such an approach is suggested due to its ease and objectivity. Sole use of mandatory criteria to define computer service requirements, however, is appropriate only when a user has a well justified set of functional (nonmeasurable) and performance (measurable) requirements. The latter occurs if there exist threshold levels of performance for which "better" performance represents no significant improvement satisfying processing needs. For example, in a in particular application, a service for which 80% of its responses occur in less than two seconds may be for practical purposes just as good as a service for which 80% of its responses occur in less than one second. That is, as long as 80% of its responses occur in less than two seconds, a service is considered acceptable. Once a certain threshold level of performance is assured, other considerations such as cost and available software become more important factors in the selection process.

A second approach for use in more complex selections applies a set of mandatory criteria (thereby reducing the original set of services to a set of minimally acceptable ones) and then applies a set of desirable criteria. For each desirable criterion satisfied, a service is rewarded an amount (either in dollars or points) which represents the effort required for the user to make up for the service feature had it been lacking. After all desirable criteria are applied, the service with the lowest cost or score is selected. This technique is part of a cost-value selection methodology detailed in [JOS77] and summarized in [TIM73]. Other selection methodologies define a weights and scores approach [DOW67] and a figure of merit approach [ABR77b]. The reader should be familiar with one or more of these techniques to understand fully how the procedures described below fit into the overall selection process.

Regardless of the selection methodology used, information about the computer services being compared with respect to particular performance indices is needed. The procedures presented in this publication determine which services perform at specified performance threshold levels when those levels are expressed in terms of proportion statistics. If the procedures are applied in phase II of a selection process, the included services continue to be considered for selection, while the excluded services are eliminated. If the procedures are applied in phase IIIB of a selection process, the included services are properly rewarded and/or the excluded services are properly penalized. In general, the procedures are employed as part of a binary decision making process. Each procedure provides the analyst with a confidence statement which characterizes a comparison study's probability of success. That is, confidence statements similar to, "we are 90% confident that services x, y, z provide a specified level of performance while services a, b, c do not" can be made after measurement.

For computer service measurement analyses, there are four steps which must be followed to collect meaningful measurements from the computer services being compared. They are:

- determination of performance criteria which will form the basis of a service comparison [ABR77b],
- development of a user scenario that is representative of a projected workload [CR074, NOL74, WAT77, WRI76],
- translation of a scenario into individual scripts executable on the respective services under test [MAM79a], and
- 4. collection and analysis of the data required for a comparison.

The procedures now presented address issues relevant to step four; some references for the others are provided.

3.0 APPLICATION OF PROPORTION CRITERIA

The application of proportion criteria in a computer service selection occurs when an analyst wants to know which services provide a minimum level of performance. The efficiency of the data collection process and the validity of the data analysis in making the binary decisions required such an application depend upon the choice of an in appropriate experimental design. An area of statistics entitled "Statistical Ranking and Selection" provides an appropriate foundation for the data collection and analysis component of a computer service comparison and selection [GIB77] for a survey of ranking (see [DUD78] and or selection techniques).

The statistical ranking and selection literature refers to the binary decision making process as selection "better than a standard" or "subset selection". <u>Reference in this</u> <u>publication to a service as being better than standard is an</u> <u>attempt to be consistent with this literature and does not</u> <u>imply a "standard" such as a voluntary national standard or</u> <u>a Federal Information Processing Standard</u>. Subset selection procedures based on a proportion statistic are appropriate for the application of measurable criteria in a computer service selection. Three of these procedures are described here.

The actual step-by-step procedures that are presented in this section, combined with Tables 1-19 in Appendix B of SP 500-44 and Appendices A and B here, are complete in that they may applied without reference to other books or articles. No statistical justification for the procedures is presented; the interested reader is referred to [AME79] and [AME80] for the statistical theory. Other references describing the application of ranking and selection theory to computer selection include [AME78] and [MAM77].

To those readers for whom this is a first exposure to ranking and selection procedures, it is suggested that Sections 3.2.1, 3.2.2 and 3.2.3 be read in parallel with Sections 4.2.1, 4.2.2 and 4.2.3, respectively, where example applications of the procedures are given. 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.

3.1 Proportion Criteria

As quoted in Section 2.0, [FIP57] recommends the use of non-parametric statistical descriptors when specifying computer service response time and turnaround time. In particular, it is recommended that in specifying acceptable computer service response, one or more classes of interactive tasks be specified to the degree required by the complexity of the workload. The examples given are:

1. In the use of the text editor for insertions, deletions or changes involving n characters or less, the response time shall be less than w seconds 50% of the time.

2. In the compilation of PL/I programs of less than m lines, the response shall be x seconds or

less 90% of the time.

3. Retrieval requests to a bibliographic information retrieval service, in which p criteria (keys) shall all be satisfied in order for an item to be displayed, shall be serviced with a response time of u seconds or less 95% of the time.

These are all examples of "single" proportion criteria; each one defines a single threshold level of performance (w seconds, x seconds, u seconds) and an associated minimum proportion (50%, 90%, 95%). (Note that percentages such as 50%, 90%, 95% are equivalent to proportions of 0.50, 0.90, 0.95, respectively.)

It also is possible for the user to increase the complexity of a selection criterion (and likewise the complexity of the associated data analysis) by using multiple proportion statistics in specifying acceptable response. For instance, number 1. above could be restated as:

1'. In the use of the text editor for insertions, deletions or changes involving n characters or less, the response time shall be less than w seconds 50% of the time and less than 2w seconds 85% of the time.

This is an example of a "dual" proportion criterion since it defines two threshold levels of performance (w seconds, 2w seconds) and two associated minimum proportions (50%, 85%).

Procedures for the application of single and dual proportion criteria are discussed in Sections 3.2.1 and 3.2.2, respectively. A procedure for the application of an "upper-lower" proportion criterion, a variation of a single proportion criterion, is discussed in Section 3.2.3.

A basic set of definitions common to ranking and selection procedures is presented in Table 2 for easy reference. Table 2 should be read in conjunction with the next section. The notation is consistent with the statistical ranking and selection literature and will facilitate reference to that literature.

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Table 2 Summary of Ranking and Selection Terminology

Α.	Notation common to all procedures						
	k:	number of computer services in the study					
	P*:	desired level of confidence in the correctness of the selection results; P* is a probability of correct selection					
	n:	number of measurements collected from each computer service					
	<pre>service(i):</pre>	the ith computer service; i = 1, 2,, k					
Β.	Notation common to	selection based on single proportion criteria					
	C(thld):	measure threshold value for a performance index					
	X(i):	number of measurements from service(i) which are less than C(thld)					
	p(min):	minimum proportion of measurements less than C(thld) required to include a service in a selected subset					
	p(i):	true proportion of measurements from service(i) which are less than C(thld)					
C.	Notation common to	selection based on dual proportion criteria					
	Cl(thld): C2(thld)	first and second measure threshold values for a performance index					
	Xl(i), X2(i):	number of measurements from service(i) which are less than Cl(thld), C2(thld), respectively					
	pl(min), p2(min):	minimum proportion of measurements less than Cl(thld) C2(thld), respectively, required to include a service in a selected subset					
	pl(i), p2(i):	true proportion of measurements from service(i) which are less than Cl(thld), and greater than or equal to C2(thld), respectively					
D.	Notation common to	selection based on upper-lower proportion criteria					
	C(thld):	measure threshold value for a particular index					
	X(i):	number of measurements from service(i) which are less than C(thld)					
	p_upper(min):	minimum proportion of measurements less than $C($ thld $)$ required to include a service in a selected subset					
	p_lower(max):	maximum proportion of measurements less than C(thld) required to exclude a service from a selected subset					
	p(i):	true proportion of measurements from service(i) which are less than C(thld)					

3.2 Procedures for the Application of Proportion Criteria

For selection based on proportions, it is assumed that there are k > 0 computer services from which it is desired to determine a subset of <u>minimal</u> size which includes all computer services satisfying a specific performance requirement. Each procedure achieves a correct subset selection with probability at least P* (0 < P* <1). The value P* is prespecified; its complement 1-P* is the upper bound on the probability of an incorrect selection. (That is, the selection procedures limit the probability of an incorrect selection to no more than 1-P*.)

For each procedure, it is necessary to obtain n independent measurements from each computer service. 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 related to or dependent on the value of one or more previous measurements. In a comparison study, correlation among data points would exist if measurement collection did not account for the periodic nature of the workload demands. For example, if the processing requests on a computer service significantly change during certain periods of the day, consecutive measurements taken over short time intervals are likely to be correlated. That is, a fast (slow) response time data point is likely to follow a fast (slow) response time data point if the time interval between collection is not long enough to negate the periodic effect.

SP 500-44 contains an extensive discussion of the statistical notion of correlation and how it relates to computer service data collection. In general, if data are correlated, the number of measurements needed for a given probability of making a correct selection increases dramatically since correlated measurements provide less "information" than do independent measurements. There are many techniques, however, for avoiding correlation in the data, such as properly spacing measurement collection in order to assume independence. With careful planning, adequate time over which to spread measurement, and reasonably well-behaved computer services, a correlation problem often can be avoided without violating experimental objectives. (+)

⁽⁺⁾ In some cases a correlation problem is unavoidable. The author is developing procedures which take correlation into account.

A significant advantage of these procedures is that they make no assumptions about the underlying distribution of the measurements. That is, one need not assume that response times, turnaround times, etc., follow a normal, exponential, or any other often assumed distribution.

The goals of the procedures are:

Section 3.2.1 - Determining S(single), a subset of computer services that includes all services better than a single proportion criterion.

Section 3.2.2 - Determining S(dual) - a subset of computer services that includes all services better than a dual proportion criterion.

Section 3.2.3 - Determining S(upper-lower) - a subset of computer services that includes all services <u>better</u> than an upper proportion criterion and excludes all services <u>worse</u> than a lower proportion criterion.

3.2.1 Selection of Services Satisfying a Single Proportion Criterion

A single proportion criterion is stated in terms of a measure threshold value, C(thld), and a minimum proportion, p(min). The object of the procedure is to determine a subset of the k computer services being compared which includes every service whose performance distribution (for a particular index) has values less than C(thld) at least p(min) proportion of the time. (+) The true proportion of values from the ith computer service, denoted service(i), which are less than C(thld) is denoted p(i).

For example, if a performance index of interest is turnaround time for a certain sequence of user-computer interactions, then a single proportion criterion might state that at least eighty percent of the time the sequence must be executed in less than 10 minutes. In this case, p(min) =0.80 and C(thld) = 10 minutes.

(+) One can determine a subset which includes every computer service whose performance distribution has values greater than C(thld) at least p(min) proportion of the time by replacing "less" (<) with "greater" (>) wherever values of C(thld) are referenced. The values of the parameters C(thld) and p(min) (and analogous parameters in the two procedures that follow) are analyst choices based on nonstatistical considerations such as past performance or projected performance needs. These values also may be the results of psychological studies of human-computer interaction studies which indicate threshold levels of computer performance necessary for efficient and/or acceptable human performance [CAR68, MIL68, WIL77]. For example, [MIL68] indicates that most response delays in conversational interaction between human and information systems must be less than 15 seconds. (In this case, "most" might be interpretted as 90%.)

Selection is accomplished by collecting measurements from the computer services under study and estimating each service's p(i) value. Using an appropriate decision rule based on statistical ranking and selection theory, the analyst is then able to determine those computer services which satisfy the single proportion criterion.

Denoting S(single) as the selected subset of computer services, by definition a correct selection occurs if and only if:

 $\forall i[p(i) \ge p(min) \longrightarrow service(i) \in S(single)]$

That is, for each and every service, if the proportion of values less than a threshold is greater than or equal to a minimum proportion value, then that service is included in the selected subset (see Figure 2).

When applying proportion criteria, an analyst would prefer a procedure which perfectly separated all "better than (or equal to) standard" computer services from all "worse than standard" services. With only a finite number of measurements from which to draw inference, any rule separating "better" services from "worse" services will have positive probability of two kinds of selection error: that of excluding better services, and that of including worse services. Based on practical considerations in procurement situations, it is assumed better to minimize the chance of the latter type of selection error (i.e. it is better to include a "worse" service than to omit a "better" one). This attitude is justifiable in government procurement where efforts must be made to minimize the chance of incorrectly claiming a vendor's product to be below specifications.

EXAMPLE: SELECT ALL SERVICES WHICH HAVE AT LEAST 80% TURNAROUND TIMES LESS THAN 10 MINUTES

C(thld) = 10 MINUTES p(min) = 0.80

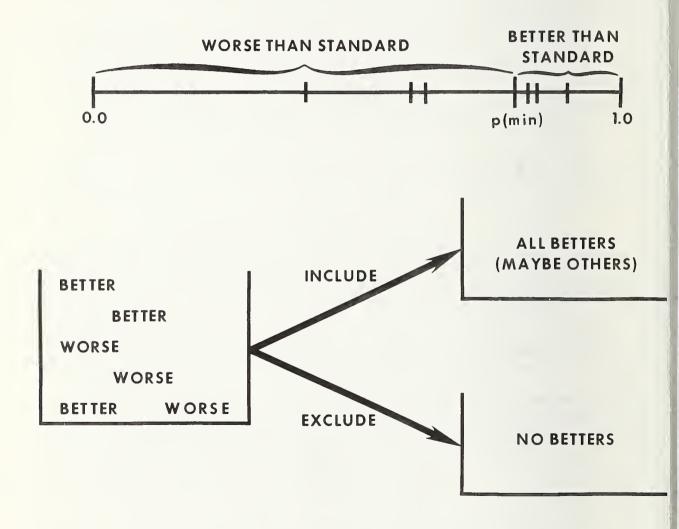


FIGURE 2: APPLICATION OF A SINGLE PROPORTION CRITERION

Therefore this procedure determines (with probability at least P*) a subset of services which <u>includes</u> all services that perform better than C(thld) at least p(min) proportion of the time. Other assumptions regarding the two kinds of selection errors result in different subset selection procedures; they are not investigated here. This selection goal is extended in the procedure in Section 3.2.3 where an analyst has some control over how far below standard a service can be, and still be included in the selected subset.

Note that for a subset selection policy, there is also an implicit objective of minimizing the size of the selected subset (subject to a 1-P* constraint on the probability of incorrect selection). One can always attain a correct subset selection with probability equal to one by including all services in a selected subset (since such a subset indeed would <u>include</u> all better than standard services), yet this contradicts the purpose of applying proportion criteria - that of detecting as many worse than standard computer services as possible.

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 practical considerations, bearing in mind that as n increases, more accurate estimates of each service's proportion will be attained, thereby increasing the chances of excluding those services whose performance does not satisfy the single proportion criterion.

<u>Step</u> 3: Let X(i) = number of measurements from service(i) which are < C(thld). Since n is identical for each computer service, the X(i) values provide information about the true proportions.

<u>Step 4</u>: For each service, compare X(i) to a constant M, which is derived from statistical ranking and selection theory. If X(i) \geq M, then include service(i) in the selected subset; otherwise exclude it. M is determined by table lookup based on the parameters k, n, P* and p(min). Extensive values for M are tablulated in [AME79] and are reproduced as Tables 1-19 in Appendix B of SP 500-44. (In these tables p(min) is referred to as the standard proportion.)

3.2.2 Selection of Services Satisfying a Dual Proportion Criterion

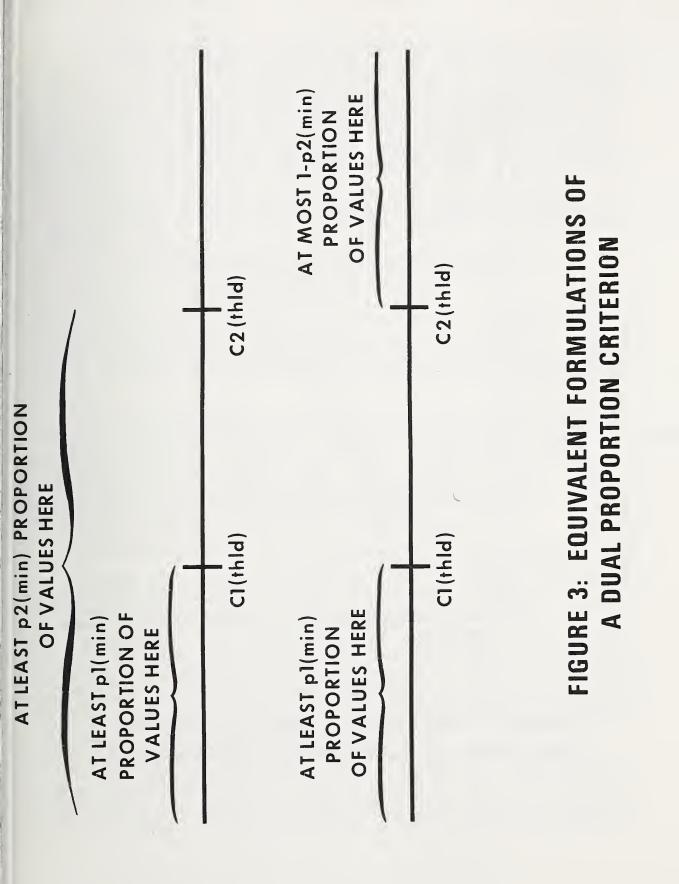
A dual proportion criterion is stated in terms of two measure threshold values, Cl(thld) and C2(thld), and two minimum proportions, pl(min) and p2(min). The object of the procedure is to determine a subset of the k computer services being compared which <u>includes</u> every service whose performance distribution (for a particular index) has values less than Cl(thld) at least pl(min) proportion of the time <u>and</u> has values less than C2(thld) at least p2(min) proportion of the time. (+) (Assuming without loss of generalization that Cl(thld) < C2(thld), then to be meaningful pl(min) < p2(min).) The latter part of a dual proportion criterion equivalently can be stated as "has values greater than or equal to C2(thld) at most 1-p2(min) proportion of time" (see Figure 3).

For example, if a performance index of interest is response time for program compilations, then a dual proportion criterion might state that at least 60% of the compilations must take less than thirty seconds and at least 90% of the compilations must take less than one minute. In this case pl(min) = 0.60, p2(min) = 0.90, Cl(thld) = 30seconds and C2(thld) = 1 minute.

The values of the parameters Cl(thld), C2(thld), pl(min), and p2(min) are analyst choices based on nonstatistical considerations. Selection is accomplished by collecting measurements from each computer service under study and estimating the true proportions of measurements from service(i) lying below Cl(thld) and C2(thld).

Performance measurements from the computer services fall into one of three intervals; interval l = [0,Cl(thld)), interval 3 = [Cl(thld),C2(thld)) and interval 2 = [C2(thld), infinity). (Note that the intervals are ordered 1,3,2 and not 1,2,3.) The <u>true</u> proportions of measurements from service(i) which lie in the intervals 1,3,2 are denoted pl(i), l-pl(i)-p2(i), and p2(i), respectively (see Figure 4).

(+) Justification for determining a subset which <u>includes</u> all better than standard services rather than one which precisely separates the better than standard services from the worse than standards services is discussed in Section 3.2.1.



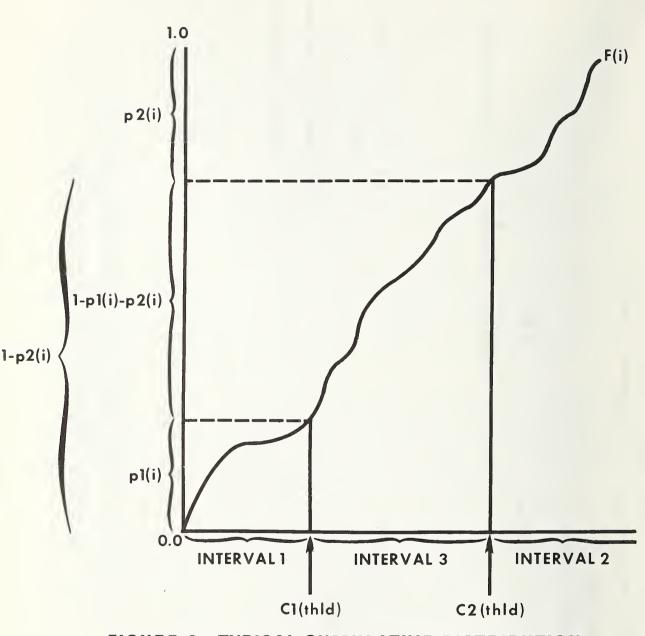


FIGURE 4: TYPICAL CUMULATIVE DISTRIBUTION FUNCTION F(i) OF OBSERVATIONS FROM SERVICE(i)

A dual proportion criterion defines service(i) to be better than standard if $pl(i) \ge pl(min)$ and $1-p2(i) \ge$ p2(min). Stated in other terms, pl(min) is a minimum probability of a measurement lying in interval 1, and p2(min) is a minimum probability of a measurement lying in the union of intervals 1 and 3. (Note that the latter part of this statement is <u>not</u> equivalent to saying p2(min)-pl(min) is a minimum probability of a measurement lying in interval 3.)

Denoting S(dual) as the selected subset of computer services, by definition a correct selection occurs if and only if:

 $\forall i [\{ pl(i) \ge pl(min) \text{ and } l-p2(i) \ge p2(min) \} \\ --> \text{ service}(i) \in S(dual)]$

That is, for each and every service, if the proportions of values less than both threshold values are greater than or equal to two minimum proportion values, respectively, then that service is included in the selected subset (see Figure 5).

A dual proportion criterion permits greater flexibility than a single proportion criterion in defining performance requirements in a computer service comparison effort by specifying two, rather than one, statistical values of interest of a performance distribution. The added flexibility of a dual criterion is attained at the expense of a more complex experimental design.

The procedure is a four step process:

<u>Step 1</u>: Choose appropriate P*, Cl(thld), C2(thld), pl(min) and p2(min) values according to nonstatistical considerations.

<u>Step 2</u>: Collect n independent measurements from each of the k computer services. The analyst chooses n based on practical considerations, bearing in mind that as n increases more accurate estimates of each service's proportions will be attained, thereby increasing the chances of excluding those services whose performance does not satisfy the dual proportion criterion.

Step 3: Let X1(i) and X2(i) = number of measurements
from service(i) which are < Cl(thld) and < C2(thld),
respectively. Since n is identical for each computer
service, the X1(i) and X2(i) values provide information</pre>

EXAMPLE: SELECTALL SERVICES WHICH HAVE AT LEAST 60% RESPONSE TIMES LESS THAN 30 SECONDS & AT LEAST 90% RESPONSE TIMES LESS THAN 60 SECONDS C1(thld) = 30 SECONDSp1(min)=0.60C2(thld)=60 SECONDS p2(min)=0.90WORSE THAN STANDARD 1 **BETTER THAN STANDARD 1** 0.0 pl(min) 1.0 **BETTER THAN WORSE THAN STANDARD 2** STANDARD 2 0.0 1.0 p2(min) ALL BETTER-BETTERS (MAYBE OTHERS) INCLUDE WORSE-WORSE BETTER-BETTER WORSE-BETTER **BETTER-BETTER** EXCLUDE **BETTER-WORSE** NO BETTER-BETTERS

FIGURE 5: APPLICATION OF A DUAL PROPORTION CRITERION

about the true proportions.

<u>Step 4</u>: For each service, compare X1(i) and X2(i) to constants M1 and M2, respectively, which are derived from statistical ranking and selection theory. If X1(i) \geq M1 and X2(i) \geq M2, then include service(i) in the selected subset; otherwise exclude it. M1 and M2 are determined by table lookup based on the parameters k, n, P*, p1(min) and p2(min). Extensive values of M1 and M2 are tabulated in [AME79] and are reproduced as Tables 5-24 in Appendix A. (In these tables p1(min) and p2(min) are referred to as standard proportions 1 and 2, respectively.)

3.2.3 Selection of Services Satisfying an Upper-Lower Proportion Criterion

This procedure is a variation of the procedure described in Section 3.2.1. In that section, it is assumed that there are k > 0 computer services being compared from which a subset is determined that includes all services satisfying a specific single proportion criterion. Such a procedure does not control how far below standard a computer service can perform and still be included in the selected subset. (Although the farther below standard a service performs in general, the greater the probability that it will be excluded as a result of a particular empirical study) The procedure only achieves with confidence P* that all better than standard services are included. Therefore it is possible to obtain a correct selection and include several worse than standard services.

For this procedure it is assumed that there are k > 0computer services from which a subset is determined that includes all services better than an "upper" proportion criterion and that excludes all services worse than a "lower" proportion criterion. An upper-lower proportion criterion is stated in terms of a measure threshold value, C(thld), and minimum upper and maximum lower proportions, $p_upper(min)$ and $p_lower(max)$. The object of this procedure is to determine a subset 1) that includes every computer service whose performance distribution (for a particular index) has values less than C(thld) at least $p_upper(min)$ proportion of the time and 2) that excludes every service whose performance distribution (for the same index) has values less than C(thld) at most $p_lower(max)$ proportion of the time. (Note that if $p_upper(min) = p_lower(max)$, the problem reduces to perfectly separating better services from worse services for a single proportion criterion. As discussed in Section 3.2.1, with only a finite number of measurements to estimate the true proportions, perfect separation is not possible.)

For example, if a performance index of interest is edit command response time, then a performance criterion might state that at least seventy percent of the response times must be less than three seconds. Using the procedure in Section 3.2.1, a comparison study could determine a subset of services which includes all services for which at least 70% of the responses are less than three seconds. Using the procedure below, an analyst could design the same study also to exclude, with probability P*, all services whose percentage (proportion) was less than 50% (0.50). In this case, p_upper(min) = 0.70, p_lower(max) = 0.50 and C(thld) = 3 seconds.

The values of the parameters C(thld), p_upper(min) and p_lower(max) are analyst choices based on nonstatistical considerations. Service selection is accomplished by collecting measurements from the computer services under study and estimating each one's p(i) value.

Denoting S(upper-lower) as the selected subset of computer services, by definition a correct selection occurs if and only if:

That is, for each and every service, if p(i) is greater than or equal to a minimum upper proportion value, then that service is included in the selected subset. And if p(i) is less than or equal to a maximum lower proportion value, then that service is excluded from the selected subset. No statement is made about those services for which $p_upper(min) > p(i) > p_lower(max)$ (see Figure 6).

An upper-lower proportion criterion provides more control than a single proportion criterion does in applying proportion criteria in the selection process. It does so by permitting an analyst to regulate how poorly a service can perform and still be selected due to variability in the collected measurements.

An upper-lower proportion criterion differs from a single or dual proportion criterion in that for the latter two types of criteria, the analyst chooses n bearing in mind EXAMPLE: SELECT ALL SERVICES WHICH HAVE AT LEAST 70% RESPONSE TIMES LESS THAN 3 SECONDS ALSO GUARANTEEING TO EXCLUDE ALL SERVICES WITH AT MOST 50% RESPONSE TIMES LESS THAN 3 SECONDS.

p-upper (min) = 0.70 p-lower (max) = 0.50

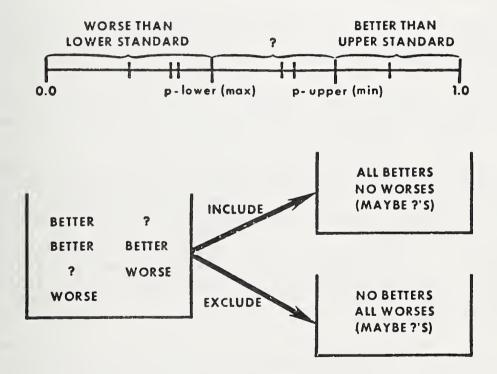


FIGURE 6: APPLICATION OF AN UPPER-LOWER PROPORTION CRITERION

only practical considerations and a desire to detect as many worse than standard services as possible. Applying an upper-lower criterion, however, requires a minimum number of measurements which must be collected for a given combination of parameter values. This is because n must be large enough to differentiate at the desired confidence level between those computer services better than the upper standard proportion and those services worse than the lower standard proportion.

The procedure is a four step process:

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

Step 2: Collect n independent measurements from each of the k computer services. The analyst chooses n based on table lookup in Appendix B.

<u>Step</u> <u>3</u>: Let X(i) = number of measurements from service(i) which are < C(thld). Since n is identical for each computer service, the X(i) values provide information about the true proportions.

<u>Step 4</u>: For each service, compare X(i) to a constant M, which is derived from statistical ranking and selection theory. If X(i) \geq M, then include service(i) in the selected subset; otherwise exclude it. M is determined by table lookup based on the parameter values k, n, P*, p_upper(min) and p_lower(max). Extensive values for M are tabulated in [AME79] and are reproduced as Tables 25-44 in Appendix B. (In these tables p_upper(min) and p_lower(max) are referred to as upper and lower standard proportions, respectively.)

Table entries in Appendix B are computed as (n,M) pairs such that if n measurements are collected in Step 2, a decision rule will exist in the form stated in Step 4. Three (n,M) pairs are computed for each combination of k, P*, p_lower(max) and p_upper(min). The first pair indicates the minimum n for which a decision rule that satisfies the P* requirement exists. The next two pairs are for larger n in the situation when an analyst can afford more data and wants the same P* value. Larger n values result in more accurate estimates of p(i) and therefore in a more accurate selection process.

4.0 COMPARISON RESULTS

Using the procedures above, this section reanalyzes computer service measurement data collected in a case study performed at the National Bureau of Standards during Summer 1978. The purpose of reanalyzing past data is to illustrate the selection procedures in terms of an actual comparison effort. The original study, discussed in detail in SP 500-44, was conducted to evaluate the time and cost required to apply various statistical ranking and selection procedures in an actual computer service procurement environment. Case study results in terms of the theoretical, technical and economic feasibility of comparing interactive computer services can be found in [MAM79b].

4.1 Summary of a Case Study

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 MVT/TSO, and a UNIVAC 1108 running Exec 8. A "scenario", or functional description of an interactive benchmark which is to be executed and measured on each computer service being compared [WAT77], was designed to be reasonably typical of the functional requirements of a real workload. It was not expected nor supposed to be representative of a specific user's workload; rather the scenario was designed to be a realistic example which could be used to investigate the overall selection methodology. The scenario is presented in Table 3.

The scenario was translated into "equivalent" scripts executable on the four services. Eight performance indices based on the activities in the script were chosen for computer service comparison in the case study. They are:

- 1. cost,
- 2. turnaround time for the entire script execution,
- response time for the bibliographic retrieval (no. 2 in the scenario),
- 4. response time for the FORTRAN program (no. 3

Note: Reference to commercial products in this report is for identification only and does not imply endorsement by the National Bureau of Standards.

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.
 - Files for executing COBOL search 1. а of а bibliographic database: compiled COBOL program SELECT: bibliographic database BIB: ACCESS: bibliographic entries to be found CHOSEN: list of entries retrieved RESULT: summary of search
 - Files for executing a FORTRAN version of the BELL 2. benchmark: BELL: compiled FORTRAN program BELLIN: input specifications for the program run BELLOUT: output of program run
 - File for interactive FORTRAN program, 3. INTERA, а source program (with errors) to compute prime numbers

Functional Script: 1. Logon to the system.

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

ARE YOU TESTING A NUMBER? (0 or 1) Enter: Ø (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? (Ø or 1) Enter: Ø (CR)

ARE YOU GENERATING PRIMES? (0 or 1)

- Enter: <u>Ø (CR)</u> DO YOU WANT TO QUIT? (Ø or 1)
 - Enter: 1 (CR)

9. Delete INTRl file. Logoff system. 10.

in the scenario),

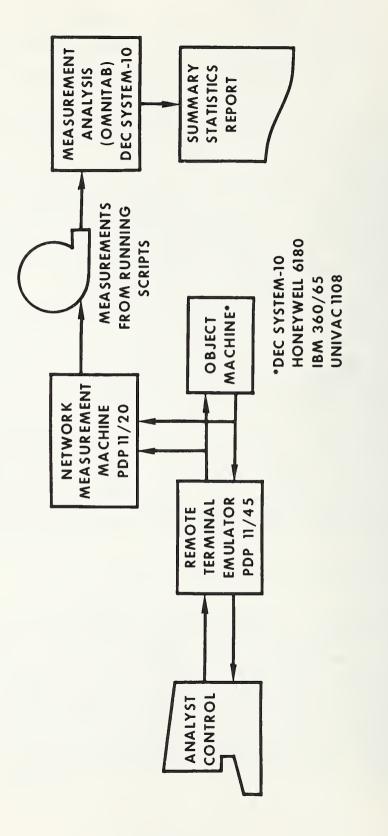
- response time for the copy command (no. 4 in the scenario),
- response time for the first edit command (no. 5 in the scenario),
- 7. response time for the second edit command (no. 6 in the scenario), and
- response time for the interactive calculation of all prime numbers less than 100 (no. 8 in the scenario).

The hardware/software configuration for the case study is illustrated in Figure 7. The scripts were repeatedly executed on each of the computer services 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.

In the case study comparison results, the four computer services are referred to as service 1, 2, 3 and 4. The numbers were 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 <u>system</u> is better than the others, but only that a given computer <u>service</u> is better. The results of the case study are not to be construed as an endorsement of any one computer service.

4.2 Application of Proportion Criteria

The purpose of the case study was to demonstrate several selection procedures each of which might require a different number of computer service measurements. Therefore a maximum number anticipated for any selection procedure was collected. In a real application of performance criteria using ranking and selection procedures, the number of measurements as well as the selection criteria are determined in advance. Initially the scripts were executed 120 times on each service, resulting in 120 measurements for each of the eight performance indices listed in Section 4.1. Due to the independence requirement,



Hardware/Software Configuration for the Case Study Figure 7

each data set was eventually reduced to 90 (independent) measurements for each index. (See SP 500-44: Appendix A and Section 3.2.2 for a discussion of reduction techniques.)

In the examples that follow, proportion criteria which likely would be used in an actual procurement are chosen. Each example employs one of the experimental procedures presented in Section 3.2. (Additional examples can be found in [AME79] and [MAM79a].) In those examples requiring n < 90 measurements from each computer service for a given level of confidence, the first n measurements were chosen. In a real comparison, when application of one criterion requires fewer measurements than are collected to satisfactorily apply another criterion, it is statistically acceptable (and, in fact, strongly advisable) to use more than the required number of measurements. The examples use the minimum number of measurements for purposes of clarity only.

In the examples, the values of those parameters which are analyst choices were specified to make the examples as clear and explicit as possible. Efforts also were made to select parameter values that are likely to be chosen in a computer service selection process. The steps in the examples parallel the steps in the original presentations of the procedures in Sections 3.2.1, 3.2.2 and 3.2.3.

Table 4 presents various summary statistics for the four computer services. Only the proportion information (i.e. the column titled "No. Measurements < C(thld)") is used in the examples below. The mean and quantile statistics are presented to provide a more detailed comparison picture. The complete set of n = 90 independent measurements were used for the calculation of all statistics in Table 4 except where a different n value is indicated.

4.2.1 Selection of Services Satisfying a Single Proportion Criterion (2 examples)

Example (parallels Section 3.2.1)

Step 1: Suppose it is a mandatory criterion that a computer service be able to interactively calculate the prime numbers between 1 and 100 (no. 8 in Table 3) in less than 1.00 second at least 80% of the time. Further, suppose it is desired to select a subset which includes all such services with a probability of correct selection at least

84 96 84 84
28.10 2.60 50.61 20.22
10.06 .80 21.31 7.00
12.91 1.19 30.27 11.32
н и м 4
4. Response time for FORTRAN synthetic program (sec.)

(+) n=90 except where otherwise specified

C(th14)=3.0	8-00 44 00 27	=3.0	-3.0	1.0
C(thld)=3.0	n=30 22 25 00 16	c(thld)= 84 90 50 57	C(thld)=3.0 87 90 62 61	с(thld)= 49 74 32
	3.99 4.45 44.32 9.12	2.63 .15 9.49 6.27	1.93 .15 8.13 4.87	2.37 .15 6.80
	1.59 2.05 18.54 3.69	.92 .15 2.06		.92 .12 .60
	2.27 2.53 2.74 4.26	1.24 .15 4.18 3.50	1.05 .15 4.38 3.63	1.21 .13 .76 2.62
	то м т	to o to	t a n t	H N N H
Table 4 (continued)	 Response time for copy command (sec.) 	6. Response time for first edit (sec.)	 Response time for second edit(sec.) 	 Response time for calculation of prime numbers (sec.)

0.90. Then k = 4, $P^* = 0.90$, C(thld) = 1.00 and p(min) = 0.80.

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

Step 3: For the computer services under study, Table 4 indicates that X(1) = 49, X(2) = 90, X(3) = 74 and X(4) = 32.

Step 4: Table 3 in Appendix B of SP 500-44 shows that M = 64 for this example. Therefore include services 2 and 3 and exclude services 1 and 4, i.e. S(single) = {service(2), service(3)}. Since the criterion was mandatory, services 1 and 4 would be eliminated from the selection process.

(parallels Section 3.2.1)

Step 1: Suppose it is a desirable criterion that a computer service be able to process the first edit command (no. 5 in Table 3) in less than 3.00 seconds at least 70% of the time. So, k = 4, C(thld) = 3.00 and p(min) = 0.70. Let P* = 0.95.

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

Step 3: For the four computer services, Table 4 indicates that X(1) = 84, X(2) = 90, X(3) = 50 and X(4) = 57.

 $\frac{\text{Step 4: Table 3 in Appendix B of SP 500-44 shows that}{53 \text{ for this example. Therefore, include services 1, 2} and 4 and exclude service 3, i.e. <math>S(\text{single}) = \{\text{service(1), service(2), service(4)}\}$. Since the criterion was desirable, services 1, 2 and 4 would be appropriately rewarded.

Note that if ranking and selection techniques were not being applied in this example, then service 4 might have been excluded since the "expected" number of responses less than 3.00 seconds for a service providing minimally acceptable response is 70% of 90 or 63, and X(4) < 63. But the ranking and selection procedure indicates that because of experimental variation service 4 cannot be excluded at the 95% confidence level. 4.2.2 Selection of Services Satisfying a Dual Proportion Criterion (l example)

Example (parallels Section 3.2.2)

<u>Step 1</u>: Suppose it is a desirable criterion that a computer service be able to perform the bibliographic retrieval (no. 2 in Table 3) in less than 8.0 seconds at least 40% of the time and in less than 10.0 seconds at least 70% of the time. Further, suppose it is desired to select a subset which includes all such services with a probability of correct selection at least 0.90. Then k = 4, Cl(thld) = 8.0, C2(thld) = 10.0, pl(min) = 0.40, p2(min) = 0.70, and P* = 0.90.

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

<u>Step 3</u>: For the four computer services, Table 4 indicates that: X1(1)=38 X2(1)=52 X1(2)=90 X2(2)=90 X1(3)= 0 X2(3)= 0 X1(4)=78 X2(4)=80

<u>Step 4</u>: Table 8 in Appendix A shows that (M1,M2) = (27,52) for this example. Therefore include services 1, 2 and 4 and exclude service 3, i.e. S(dual) ={service(1), service(2), service(4)}. Since the criterion was desirable, services 1, 2 and 4 would be appropriately rewarded.

4.2.3 Selection of Services Satisfying an Upper-Lower Proportion Criterion (1 example)

> Example (parallels Section 3.2.3)

<u>Step 1</u>: Suppose it is a mandatory criterion that a computer service be able to perform the entire script (1-10 in Table 3) in less than 8.0 minutes at least 80% of the time. Further, suppose it is desired to select, with probability of correct selection 0.90, a subset which includes all such services and excludes any service which performs the script in less than 8.0 minutes less than 60% of the time. Then k = 4, C(thld)= 8.0, p_upper(min) = 0.80, p_lower(max) = 0.60, and P* = 0.90.

Step 2: Choose n = 77 (based on Table 28 in Appendix B). Ninety independent measurements have been made on each computer service; choose the first 77 measurements.

Step 3: For the four computer services, Table 4 indicates that X(1)=77, X(2)=76, X(3)=9 and X(4)=43.

<u>Step 4</u>: Table 28 in Appendix B shows M = 55 for this example. Therefore include services 1 and 2 and exclude services 3 and 4, i.e. S(upper-lower) = {service(1), service(2)}. since the criterion was mandatory, services 3 and 4 would be eliminated from the selection process.

5.0 DISCUSSION AND CONCLUSIONS

One requirement for effective computer service comparison in a selection methodology is a set of procedures which can provide accurate appraisals of service behavior. Because services are compared in an uncontrolled environment, the data collection and analysis component of the selection methodology must account for the variability in the collected measurements. This publication indicates a general model of the computer service selection process based on the application of four classes of performance criteria. For use in phase II or phase IIIB of that model, where measurable criteria are applied, three binary type selection procedures are given. Based on statistical ranking and selection theory, assuming one can collect statistically independent measurements, the procedures have valid application when measurable selection criteria define computer service performance in terms of a threshold level(s) and a proportion statistic(s).

Each procedure described provides information regarding the performance of a set of computer services for a particular performance index. To arrive at a final selection of the best overall service, it may be necessary to integrate the information obtained from individually applying these procedures for several performance indices with cost estimates and other analysis results. Selection methodologies for integrating all of the available information have been referenced.

The procedures explicitly specify prior to measurement an appropriate decision rule and/or the number of independent measurements required from each computer service

to attain a given level of statistical confidence in the comparison results. The procedures are valuable in the computer service procurement process because they design comparison studies to result in statistical confidence statements about the probability of having accurately estimated computer service performance. This is in contrast to those studies which make statements about which computer services satisfy certain performance specifications, but omit statistical justification in the form of probabilistic confidence statements.

If the collection of measurements is necessary in a computer service selection, then these procedures (or similar statistically sound procedures such as those in SP 500-44) should be employed. Their mathematical derivation provides an analyst with the ability to justify the empirical results employed in the computer service selection decision making process.

6.0 ACKNOWLEDGMENTS

The author is indebted to Sandra A. Mamrak and Edward J. Dudewicz whose encouragement and guidance motivated the research on which this document is based, and to Marshall D. Abrams and the many reviewers for their significant editorial contributions.

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APPENDIX A

Tables for Dual Proportion Criteria

This appendix contains tabled values which are likely to be needed to apply the selection procedure described in Section 3.2.2. A demonstration of the use of these tables can be found in Section 4.2.2. The original source of the tables is [AME79]. In all of these tables, "population" represents a computer service, "dual standard" represents a dual proportion criterion, "P(CS)" represents the probability of correct selection, and "standard proportions 1 and 2" represents pl(min) and p2(min), respectively.

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VALUES OF M1, M2 FOR SELECTIFIC, WITH $P(CS) \rightarrow P*$. A SUBSET OF k = 3 TRINORIAL POULATIONS WHICH CONTAINS ALL POPULATIONS WITH A DUAL STANDARD (POPULATIONS WITH AT LEAST M1 OBSERVATIONS IN INTERVAL 1, AND AT LEAST M2 OBSERVATIONS IN THE UNION OF INTERVALS 1 AND 3, AUE SELECTED)

VALUES OF MI, M2 FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 4 TRINOMIL POULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A DUAL STANDAD (POPULATIONS WITH AT LEAST MI OBSERVATIONS IN INTERVAL I, AND AT LEAST M2 OBSERVATIONS IN THE UNION OF INFERVALS I AND 3, AND SELECTED)

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VALUES OF MI, WE FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 6 TRINOMLA FOULATIONS WHICH CONTAINS ALL ROPULATIONS BETTER THAN A DUAL STANDAUD (FOULATIONS WITH AT LEAST MI OBSCRAVITONS IN INTERVAL 1, AND AT LEAST PE OBSERVATIONS IN THE UNION OF INTERVALS I AND 3, ARE SELECTLD)

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VALUES OF MI, WE FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 8 TRINOMLA POULATIONS WILCH CONTINE ALL POPULATIONS FETTER TIAN A DUAL STANDAM (FOPULATIONS WILL AT LEAST MI OBSERVATIONS IN INTERVAL 1, AND AT LEAST M2 OBSERVATIONS IN THE UNION OF INTERVALS 1 AND 3, ARE SELECTED)

P.* = .90

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VALUES OF MI.M2 FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF K = 9 TRINOMULA POULATIONS WILCH CONTING ALL POPULATIONS BETTER TIAN A DUAL STANNAMU (POPULATIONS WITH AT LEAST MI OBSENVATIONS IN UNTERVAL 1, AND AT LEAST M2 OBSENVATIONS IN THE UNION OF INTERVALS 1 AND 3, ANE SELECTED)

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138 41 138</td><td>2 31 7 9112 14117 20122 26127 33132 39138 45143 52149 2 51 7 11112 17117 25122 32127 40132 47138 53149 2 61 7 14112 22117 30122 39127 47132 56138 53149 2 61 7 14112 22117 30122 39127 47132 56138 63143 73149</td><td>3 51 9 11115 18121 25127 33134 38140 47146 55153 61159 3 61 9 14115 22121 30127 39134 46140 55146 64153 72159</td><td>5 6112 13119 21126 30133 39140 48148 56155 65163 73170</td></t<></td></t<>	0 11 2 31 4 51 6 8 8 11110 15112 18115 25117 25512 25117 25512 25117 25512 25117 25512 25117 25512 25117 25512 25117 25512 25117 25512 25117 25512 25117 25512 25123 25117 25512 25123 25123 25117 25123 25123 25117 25123 25117 25123 25123 25123 25123 25112 25123 25112 25123 25112 25123 25112 25123 25112 25123 25112 25123 25112 25123 25112 25123 25123 25123 25123 25112 25123 25112 25123 25112 25123 25112 25123 25112 25123 120 120 1212 1212 1212 1212 1212 1212 1212 1212 1212 1212 1212 1212 12	1 1 3 5 6 8 9 12112 15115 27119 24 222 29125 33129 1 2 3 7 6 111 9 16112 21115 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VALUES OF MI, M2 FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF A = 11 TRINOMAL POPULATIONS WILCH CONTAINS ALL POPULATIONS BETTER THAT A DUAL STANDARD (POPULATIONS WITH AT LEAST MI OBS/RWATIONS IN INTERVAL 1, AND AT LEAST M2 OBSERVATIONS IN THE UNION OF INTERVALS I AND 3, AUE SELECTED)

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. DESC. ORGERVATI 5 RITERE

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VALUES OF MI, M2 FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF & = 12 THINOMLA POPULATIONS WILCH CONTANS ALL POPULATIONS BITTER THAN A DUAL STANDAUD (POPULATIONS WITH AT LEAST 11 ORSERVATIONS IN INTERVAL 1. AND AT LEAST M2 OBSERVATIONS IN THE UNION OF INTERVALS 1 AND 3. ANE SELECTED)

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VALUES OF MI.M2 FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 14 TRIGOILLA POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAT A DUAL STANDARD (POPULATIONS WITH AT LEAST MI OBSERVATIONS IN INTERVAL 1, AND AT LEAST M2 OBSERVATIONS IN THE UNION OF INTERVALS I AND 3, ARE SELECTED)

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        30/16         39/121         46/125         55/129         64/134         69/133</th> <th>7         8111         1416         20121         26127         31132         38137         45143         49148           7         10111         10116         25121         32127         38132         46137         54143         59148           7         13111         22116         39127         46132         55137         64143         70148</th> <th>9 11115 17121 24127 32133 39139 47146 53152 61159 9 14115 21121 30127 38133 47139 56146 63152 72159</th> <th>111 14118 22125 31133 38140 47147 56155 64162 73170</th>	3         41         6         B1         9         11112         16115         20118         24         22         5125         32128           3         61         6         10         9         15112         26115         20118         34         22         54         25         32128           3         81         6         14         9         12         251         55      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64/134         69/133</th><th>3  7 8 11 14 16 20 21 26 27 31 32 38 37 45 43 49 48 4  7 10 11 13 16 25 21 32 27 38 32 46 37 54 43 59 48 6  7 13 11 22 16 30 21 39 27 46 32 55 37 64 43 70 48</th><th>5 9 11115 17 21 24 27 32 33 39 39 47 46 53 52 61 59 6 9 14 15 21 21 39 27 38 33 47 39 56 46 63 52 61 59</th><th>6111 14118 22125 31133 38149 47147 56155 64162 73170</th></td<>	3         41         6         B1         9         11112         16115         20118         24         22         5125         32128           3         61         6         10         9         15112         26115         20118         34         22         54         25         32128           3         81         6         14         9         12         251         55         3123         34         24         25         26         25         32128           3         81         6         14         9         12         35         34         36         24         25         50         128         36         24      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  57/138           5         10         8         120/12         39/129         46/129         54/134         57/138           5         13         8         22/112         30/16         39/121         46/125         55/129         64/134         69/133	3  7 8 11 14 16 20 21 26 27 31 32 38 37 45 43 49 48 4  7 10 11 13 16 25 21 32 27 38 32 46 37 54 43 59 48 6  7 13 11 22 16 30 21 39 27 46 32 55 37 64 43 70 48	5 9 11115 17 21 24 27 32 33 39 39 47 46 53 52 61 59 6 9 14 15 21 21 39 27 38 33 47 39 56 46 63 52 61 59	6111 14118 22125 31133 38149 47147 56155 64162 73170
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   17       11       17       16	1         1         3         6         5         9         8         10         14         12         18         17         23         11           2         1         15         3         11         10         14         12         11         7         12         11         17         23         14           2         1         3         16         16         10         16         12         24         14         36         17         32         14         36         12         31         32         19         32         19         32         19         32         19         32         19         32         19         32         19         32         19         32         19         32         19         32         19         32         19         32         19         32         19         32         19         32         11         33         14         36         11         33         14         36         11         33         14         36         11         33         14         36         11         33         14         36         11         33         11 <td< th=""><th>3         41         6         B1         9         11112         16115         20118         24         22         5125         32128           3         61         6         10         9         15112         26115         20118         34         22         54         25         32128           3         81         6         14         9         12         251         55         3123         34         24         25         26         25         32128           3         81         6         14         9         12         35         34         36         24         25         50         128         36         24         128         36         25         25         50         128         36         128         112         36         14         54         128         36         128         113         37         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138</th><th>5         6         8         11/12         16/16         21/21         25/125         31/129         36/134         38/139           5         6         8         11/112         16/16         26/121         31/129         38/129         36/134         38/139           5         6         18         11/112         25/16         22/21         31/129         36/134         37/138           5         10         8         10/112         25/16         32/121         38/129         46/139         46/139         46/136         57/138           5         10         8         120/12         39/129         46/129         54/134         57/138           5         13         8         22/112         30/16         39/121         46/125         55/129         64/134         69/133</th><th>7         8111         1416         20121         26127         31132         38137         45143         49148           7         10111         10116         25121         32127         38132         46137         54143         59148           7         13111         22116         39127         46132         55137         64143         70148</th><th>9 11115 17121 24127 32133 39139 47146 53152 61159 9 14115 21121 30127 38133 47139 56146 63152 72159</th><th>111 14118 22125 31133 38140 47147 56155 64162 73170</th></td<>	3         41         6         B1         9         11112         16115         20118         24         22         5125         32128           3         61         6         10         9         15112         26115         20118         34         22         54         25         32128           3         81         6         14         9         12         251         55         3123         34         24         25         26         25         32128           3         81         6         14         9         12         35         34         36         24         25         50         128         36         24         128         36         25         25         50         128         36         128         112         36         14         54         128         36         128         113         37         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138         138	5         6         8         11/12         16/16         21/21         25/125         31/129         36/134         38/139           5         6         8         11/112         16/16         26/121         31/129         38/129         36/134         38/139           5         6         18         11/112         25/16         22/21         31/129         36/134         37/138           5         10         8         10/112         25/16         32/121         38/129         46/139         46/139         46/136         57/138           5         10         8         120/12         39/129         46/129         54/134         57/138           5         13         8         22/112         30/16         39/121         46/125         55/129         64/134         69/133	7         8111         1416         20121         26127         31132         38137         45143         49148           7         10111         10116         25121         32127         38132         46137         54143         59148           7         13111         22116         39127         46132         55137         64143         70148	9 11115 17121 24127 32133 39139 47146 53152 61159 9 14115 21121 30127 38133 47139 56146 63152 72159	111 14118 22125 31133 38140 47147 56155 64162 73170
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 53         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         32         <th< th=""><th>.60         1    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    3         11         17         23         11         7         23         11         7         23         11         7         23         11         7         23         11         7         23         11         7         23         11         7         23         11         13         11         15         16         10         23         12         24         26         11         23         13         11         16         10         13         13         14         5         12         13         13         14         5         13         11         13         13         14         15         13         13         14         15         13         13         14         13         13         14         13         13         14         13         13         14         13         13         14         13         14&lt;</td> <td>1         1         3         41         6         81         9         11112         16115         20118         24         22         55         32      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 16     17     16     16     17     16     17     17     17     17     17     17     16     17     17     17     16     16     11     17     2     16     17     17     17     17     17     17     16     17     17     16     17     17     17     17     17     17     17	0         11         1         31         3         61         5         9         8         101         14         12         18         12         13         17         23         19           0         11         1         51         3         11         5         3         11         17         23         11         7         23         11         7         23         11         7         23         11         7         23         11         7         23         11         7         23         11         7         23         11         13         11         15         16         10         23         12         24         26         11         23         13         11         16         10         13         13         14         5         12         13         13         14         5         13         11         13         13         14         15         13         13         14         15         13         13         14         13         13         14         13         13         14         13         13         14         13         13         14         13         14<	1         1         3         41         6         81         9         11112         16115         20118         24         22         55         32         28           1         2         3         61         6         101         9         15         12         26         18         24         25         32         28         12         28         12         28         12         28         24         25         41         28         28         31         28         31         28         26         12         31         28         30         22         41         28         12         31         38         28         25         56         25         32         26         12         31         30         22         56         12         31         38         28         26         12         31         15         31         15         31         15         36         12         31         36         12         31         15         36         12         31         15         36         12         31         12         36         12         31         36         12         31         12 </td <td>1         21         5         61         8         11         12         16         16         12         15         12         361         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38<td>2 31 7 8111 14116 20121 26127 31132 38137 45143 49148 2 41 7 10111 18116 25121 32127 38132 46137 54143 59148 2 61 7 13111 22116 30121 39127 46132 55137 64143 70148</td><td>3 5 9 11115 17 21 24 27 32133 39139 47 46 53152 61159 3 6 9 14115 21121 30127 38133 47 39 56 446 63152 72159</td><td>1 5 6111 14118 22125 31133 38140 47147 56155 64162 73170</td></td>	1         21         5         61         8         11         12         16         16         12         15         12         361         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38         38 <td>2 31 7 8111 14116 20121 26127 31132 38137 45143 49148 2 41 7 10111 18116 25121 32127 38132 46137 54143 59148 2 61 7 13111 22116 30121 39127 46132 55137 64143 70148</td> <td>3 5 9 11115 17 21 24 27 32133 39139 47 46 53152 61159 3 6 9 14115 21121 30127 38133 47 39 56 446 63152 72159</td> <td>1 5 6111 14118 22125 31133 38140 47147 56155 64162 73170</td>	2 31 7 8111 14116 20121 26127 31132 38137 45143 49148 2 41 7 10111 18116 25121 32127 38132 46137 54143 59148 2 61 7 13111 22116 30121 39127 46132 55137 64143 70148	3 5 9 11115 17 21 24 27 32133 39139 47 46 53152 61159 3 6 9 14115 21121 30127 38133 47 39 56 446 63152 72159	1 5 6111 14118 22125 31133 38140 47147 56155 64162 73170

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VALUES OF MI.MZ FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 15 TRINOMLAL POULATIONS WHICH CONTAINS ALL POPULATIONS DETER THAN A DUAL STANDARD (POPULATIONS WITH AT LEAST MI OZSENATIONS IN INTERVAL 1, AND AT LEAST M2 OBSERVATIONS IN THE UNION OF INTERVALS 1 AND 3, ADE SELECTED)

99. = *d

= .95 RURBER OF OBSERVATIORS(a)	STARDARD   16   26   30   40   50   60   70   80   96   160   Roportions	20     0     0     0     1     0     2     0     3     1     4     1     6     2     6     3     1     4     1     6     2     6     3     1     4     1     6     2     6     3     1     4     1     6     2     6     1     1     1     1     1     1     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     3     1     1     1     1     1     1 </th <th>30     0     0     0     1     1     3     2     4     3     7     4     9     6     10     7     13     15     10     15     13     15     10     15     13     15     10     15     13     15     14     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     16     16     17     17     15     15     16     16     16     16     16     16     16     16     16     16     16     16     16     16     17     17     12     15     15     16     16     16     16     17     17     12     16     16     17     17     12     16     17     17     13     16     16     16     16     16</th> <th>.40       0       1       2       3       5       7       10       9       13       11       23       3       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       14       13       13       13       13       13       13       13       13       14       13       13       13       13       13       13       13       14       13       13       13       13       13       14       13       13       13       14       13       14       13       14       13       14       14       14       14       14       13       15       13       14       13       15       14       13       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14<th>50         0         1         2         4         7         8         1111         15114         19117         231         20         27124         30127         351         351         351         351         361         361         37         351         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361</th><th>.60         1         21         4         61         8         101         21         4         101         21         101         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21         21&lt;</th><th>70         1         2         31         6         11         13116         18         12         133126         30         137         36         44         14         50         47         51           .00         2         41         6         1011         16         16         22121         28126         37131         45136         52141         60147         651           .90         2         61         6         13         11         2116         27         21         35126         45131         5436         52141         60147         651           .90         2         61         6         13         11         21116         277         21         35126         45131         54         36         36141         72         47         701</th><th>.80 3 41 8 10 14 17 20 24 26 31 32 30 38 46 45 51 51 60 157 68 .90 3 61 8 13 14 21 20 29 26 38 32 46 38 55 45 61 51 71 57 80</th><th>.90   4 6 11 13 18 21 23 29 32 38 39 46 46 55 54 63 61 72 69 79 </th></th>	30     0     0     0     1     1     3     2     4     3     7     4     9     6     10     7     13     15     10     15     13     15     10     15     13     15     10     15     13     15     14     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     15     16     16     17     17     15     15     16     16     16     16     16     16     16     16     16     16     16     16     16     16     17     17     12     15     15     16     16     16     16     17     17     12     16     16     17     17     12     16     17     17     13     16     16     16     16     16	.40       0       1       2       3       5       7       10       9       13       11       23       3       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       14       13       13       13       13       13       13       13       13       14       13       13       13       13       13       13       13       14       13       13       13       13       13       14       13       13       13       14       13       14       13       14       13       14       14       14       14       14       13       15       13       14       13       15       14       13       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14 <th>50         0         1         2         4         7         8         1111         15114         19117         231         20         27124         30127         351         351         351         351         361         361         37         351         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361  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     701</th> <th>.80 3 41 8 10 14 17 20 24 26 31 32 30 38 46 45 51 51 60 157 68 .90 3 61 8 13 14 21 20 29 26 38 32 46 38 55 45 61 51 71 57 80</th> <th>.90   4 6 11 13 18 21 23 29 32 38 39 46 46 55 54 63 61 72 69 79 </th>	50         0         1         2         4         7         8         1111         15114         19117         231         20         27124         30127         351         351         351         351         361         361         37         351         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361         361  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*	STAN PROPO	. 10	. 20	30	.40	.50	. 60	02.	.80
	<u>e</u> .								
RUPHER OF OPSERVATIONS( n)	I         10         120         730         140         150         160         770         180         190         190         1<00         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1 <th1< th=""> <th1< th="">         1         1</th1<></th1<>	0     0     0     0     0       0     0     0     0     0     0       0     0     0     0     0     0       0     1     0     0     0     0       0     1     0     0     0     0       0     1     0     0     0     0       0     1     0     0     0     0       0     2     0     1     0     0       0     3     0     0     0     0       0     3     0     1     0     0       0     0     1     0     0     0       0     1     0     0     0     0       0     1     0     0     0     0	0     0       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       0     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1 <td>0         1         1         3         3         6         5         8           0         2         1         5         3         8         5         12           0         2         1         5         3         8         5         12           0         2         1         5         3         14         5         5           0         3         1         1         3         18         5         25           0         3         1         9         14         5         25           0         5         1         1         3         18         5         25           0         5         1         1         3         18         5         25           0         5         1         1         5         5         5           0         5         1         1         5         5         5           0         5         1         1         5         5         5           0         5         1         1         5         5         5</td> <td>1         11         3         41         6         81         9         11           1         1         3         66         60         9         15           1         1         3         66         60         9         15           1         2         66         60         9         15           1         2         3         86         6         13         9         19           1         2         3         16         6         13         9         19           1         5         3         16         6         21         9         29           1         5         3         14         6         21         9         29</td> <td></td> <td>000 01010</td> <td>0   3 4  9 11 15 17 21 24 27 32 33 39 39 47 46 53 52 61 58 69  0   3 6  9 13 15 21 21 29 27 38 33 47 39 55 46 63 52 72 58 8 </td> <td>1 5 5 111 14118 22125 30 33 38140 47147 56155 63162 73170 80</td>	0         1         1         3         3         6         5         8           0         2         1         5         3         8         5         12           0         2         1         5         3         8         5         12           0         2         1         5         3         14         5         5           0         3         1         1         3         18         5         25           0         3         1         9         14         5         25           0         5         1         1         3         18         5         25           0         5         1         1         3         18         5         25           0         5         1         1         5         5         5           0         5         1         1         5         5         5           0         5         1         1         5         5         5           0         5         1         1         5         5         5	1         11         3         41         6         81         9         11           1         1         3         66         60         9         15           1         1         3         66         60         9         15           1         2         66         60         9         15           1         2         3         86         6         13         9         19           1         2         3         16         6         13         9         19           1         5         3         16         6         21         9         29           1         5         3         14         6         21         9         29		000 01010	0   3 4  9 11 15 17 21 24 27 32 33 39 39 47 46 53 52 61 58 69  0   3 6  9 13 15 21 21 29 27 38 33 47 39 55 46 63 52 72 58 8	1 5 5 111 14118 22125 30 33 38140 47147 56155 63162 73170 80
RUMBER OF O	ARUARUD   10   20   30   40   50   60   70   80   90   10 Portions	0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0 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19         31         19         57         7         30         14         31         15         55         7         30         14         36         17         36</td> <td>3         41         6         B1         9         11112         15         26118         24         12         29         25         72         20           3         61         6         10         9         15         12         2015         25         18         51         23         18         51         25         10         36         16         10         25         10         25         10         25         10         25         10         25         10         25         10         25         10         25         10         25         20         25         20         25         20         25         21         21         21         21         25         20         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         25         21         45</td> <td>5         6         8         11112         16116         21121         24125         396         33         42138           5         6         8         11112         16116         26112         30123         37129         44133         51138           5         61         8         16116         26116         30121         37129         45133         51138           5         13         8         22116         32121         37129         45133         51138           5         13         8         22116         32121         37125         45129         53133         61138           5         13         8         22112         39121         45125         55129         64133         72138</td> <td>3  7 8 11 14 16 20 21 26 27 31 32 38 37 45 42 51 48 4  7 10 11 18 16 25 21 32 27 37 32 46 37 54 42 61 48 6  7 13 11 22 16 30 21 39 27 45 32 55 37 64 42 73 46</td> <td>41 9 11115 17121 29127 32 33 39 39 47 46 53152 61158 61 9 13115 21121 29127 381 33 47139 55146 63152 72 58</td> <td>5111 14118 22125 30133 38140 47147 56155 63162 73170</td>	1         1         3         6         5         8         7         11         10         14         12         17         23         19           2         16         15         7         16         16         19         12         24         14         26         17         23         19           2         16         16         10         12         24         14         36         17         46         19           2         16         16         0         12         26         14         36         17         46         19           3         14         5         16         7         21         10         23         12         36         14         36         17         46         19           3         14         5         16         7         21         10         31         37         36         14         36         17         46         19         97         17         19         31         19         57         7         30         14         31         15         55         7         30         14         36         17         36	3         41         6         B1         9         11112         15         26118         24         12         29         25         72         20           3         61         6         10         9         15         12         2015         25         18         51         23         18         51         25         10         36         16         10         25         10         25         10         25         10         25         10         25         10         25         10         25         10         25         10         25         20         25         20         25         20    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        22116         32121         37125         45129         53133         61138           5         13         8         22112         39121         45125         55129         64133         72138	3  7 8 11 14 16 20 21 26 27 31 32 38 37 45 42 51 48 4  7 10 11 18 16 25 21 32 27 37 32 46 37 54 42 61 48 6  7 13 11 22 16 30 21 39 27 45 32 55 37 64 42 73 46	41 9 11115 17121 29127 32 33 39 39 47 46 53152 61158 61 9 13115 21121 29127 381 33 47139 55146 63152 72 58	5111 14118 22125 30133 38140 47147 56155 63162 73170

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VALUES OF M1, M2 FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF M = 16 TRINOMLAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN A DUAL STANDARU (POPULATIONS WITH AT LEAST M1 OBSIRVATIONS IN INTERVAL 1, AND AT LEAST M2 OBSERVATIONS IN THE UNION OF INTIRVALS I AND 3, ALE SELECTED)

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VALUES OF MI. M2 FOR SELECTING. WITH P(CS) >= P*, A SUBSET OF k = 17TRIGOMIAL POPULATIONS WILLOUTATIONS BETTER THAM A DUAL STANDARD (POPULATIONS WILL AT LEAST HI OFSERVATIONS IN INTERVAL 1, AND A STANDARD (POPULATIONS IN THE UNION OF INTERVALS 1, AND 3, ANE SELECTED) LLAST H2 OBSERVATIONS IN THE UNION OF INTERVALS 1 AND 3, ANE SELECTED)

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VALUES OF M1,M2 FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 19 THINGMILL POPULATIONS WILCH CONTINN ALL POPULATIONS BETTER THAN A DUAL STANDARD (POPULATIONS WITH AT LEAST M1 DESCRUATIONS IN INTERVAL 1, AND AT LEAST M2 OBSERVATIONS IN THE UNION OF INTERVALS 1 AND 3, ARE SELECTED)

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1         5         1         3         1         1         2         1         3         1         1         3         1         3         2         1         1         3         1         3         3         1         3         3         3         3         3         3         3         3         3         3         3         4         3         4         1         3         4         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1	.80	-	4	4	101	~	17			2	31	6	38_	ŝ		<u>۳</u>	201	61 63	56	8	67
2       21       6       01       0       13       15       19       20       23       13       03       37       36       42       14       49       45         2       4       6       10       17       15       29       120       23       123       33       45       136       42       14       49       45         2       5       6       13       10       17       15       29       29       123       36       14       17       14       70       36       46       130       57       14       17       14       70       36       46       130       57       46       30       57       36       41       41       71       45       14       71       45       14       70       14       71       45       14       71       46       16       16       12       12       12       14       14       16       14       46       15       16       46       16       16       17       14       16       16       12       14       16       16       16       16       17       16       15       16	96.		5	4	131	►	5			2	381	<u>6</u> .	461	33		58	611	32	102	36	ê
2         41         6         10110         17115         24120         31125         38130         45136         57141         5514           2         51         6         13110         21115         29120         31125         46130         55136         51141         5114           3         41         8         1014         4162         23125         33132         75136         55144         55156         605           3         51         8         1014         16120         28126         36132         75136         54144         55156         605           3         51         8         1314         21120         28132         55136         54144         55157         605         7515           4         6         1314         21120         28132         55136         54144         63150         7515           4         6         1317         7120         28130         54144         63150         7215	. 70	~	e	s	c		13			50	10	50		30		36	C.*			92	55
2         51         6         131         0         21115         29120         38123         46         30         57         36         61         41         7114           3         41         8         114         16120         233         26         30         37         35         45         44         53         50         60         5           3         51         8         131         4         112         20         28         30         33         37         35         45         46         53         50         60         5         55         53         50         50         57         55         54         46         53         50         50         57         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55         55	80	-	4	• •	0		2		4	00	-		.8	98		98	65			40	50
3         41         8         10114         16120         23126         30132         37135         45144         53150         6015           3         51         8         13114         21120         28126         30132         45130         54144         63150         6015           3         51         8         13114         21120         28126         36132         45130         54144         63150         7215           4         6         1013117         21129         36132         36130         64144         63150         7215	96.	0	5	0	13		21		6	56	Ξ.	12	9	30		36	611			46	8
3 51 8 13114 21120 28126 36132 45130 54144 63150 7215 4 6110 1317 2123 28120 36132 45130 54144 63150 7215	BO		4	ď	191		15	00	- 2	56		22		5			53	0	- 09		52
0   4 6 10  3 17 2 24 30 32 36 39 46 46 54 53 63 61 7 16	.90		5	8			2	8	8	5	9	22	10	30			631	20	72		29
	96.	<del>ل</del> ه –	9	10	ę			40			- ,										ġ

#### APPENDIX B

Tables for Upper-Lower Proportion Criteria

This appendix contains tabled values which are likely to be needed to apply the selection procedure described in Section 3.2.3. A demonstration of the use of these tables can be found in Section 4.2.3. The original source of the tables is [AME79]. In all of these tables, "population" represents a computer service, "P(CS)" represents the probability of correct selection, and "standard proportions upper and lower" represents p_upper(min) and p_lower(max), respectively.

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VALUES OF n, M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 1 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STAND				P* =	.90			,		P* =	.95		
	LOWER	n	M	n	M		M   	n	M	n	M		
.90	.80   .70   .60   .50   .40   .20   .10	86 25 15 9 5 4 4 1	1 74  21  12  7  4  3  3  1	172 50 30 18 10 8 3	 150  42  25  15  8  6  21	15 12 12	 226  64  38  22  12  9  9  2	24 13	 116  34  19  10  6  5  4  2	270 82 48 26 16 14 12 6	235  69  40  21  12  11  9  41		354  105  60  32  19  16  14  6
.80	.70   .60   .50   .40   .30   .20   .10		96  26  13  6  4  3  2	254 72 38 18 12 10 8	53  27  12  8	57 27 18 15	295  81  42  19  12  10  8	28 17 10 7	154  43  19  11  6  4  3	14 12	3131 891 401 231 131 91 71	180 84 51 30 21 18	473   135   61   36   20   14   11
.70	.60   .50   .40   .30   .20   .10	156 39 19 9 6 4	102  24  11  5  31 2	312 78 38 18 12 8	208 49 23 10 6 4	117 57 27 18	315   76   35   16   10   6	28 17 10	162  41  16  9  5	496 134 56 34	330  85  33  19  11  7	744 201 84 51 30	5001 1301 521 301 171 111
.60	.50 .40 .30 .20 .10	168 41 19 9 5	93  21  9  4  2	82 38 18	190  43  19  8  4	123 57 27	288 67 29 13 7	28 17	148  34  13  7  3	134 56 34 16	303   71   28   16   6	201 84 51	459   109   43   25   10
.50	.40 .30 .20 .10	168 39 19 9	76  16  7  3	78 38	156 331 151 61	117 57	238 52 24 10	268 67 28 13	1211	536 134 56 26	249   57   22   9	201 84 39	379  89  34  14
.40	.30 .20 .10	$156 \\ 36 \\ 15$	55   11   4	72	114 23 9			248 60 24	87   18   6	496 120 48	181 391 141	744 180 72	276 61 22
.30	.20 .10	$\begin{array}{c} 127 \\ 25 \end{array}$	32   5		67 11		103 17	204	51 81	408	107   18	612	165   29
.20	.10	86	13	172	28	258	43	1 <b>3</b> 5	20	270	43	405	68

#### VALUES OF n.M FOR SELECTING, WITH $P(CS) \ge P*$ , A SUBSET OF k = 2 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STANI	) DARD I	•		P* =	.90		1			P* =	.95		
	LOWER		M		M		 		M	n	M	n	M
.90	. 80 . 70		   116   34		   235     69	405 123	 354  105		163   47	380 114	330 96		 499  146
	.60   .50	20 13	16   10	40 26	33   21	60 39	50  32	29 17	23 i 13 i	58 34	47 27	87 51	72  41
	.40   .30   .20	7	6   5   4	14	12  11  9	21	19   16   14	9	10  6  4	28 18 12	22 13 8	27	341 211 131
	.10	3	21	6	41	9	61		31	10	7	15	11
. 80	.70   .60   .50		151  41  19	114	307   84   40	171	464   128   61		215   57   25	570 160 74	118	855   240   111	661  180  80
	.40   .30	17 10	11   6	34 20	23   13	51 30	36   20	$\frac{22}{15}$	14   9	44 30	30 19	66	46 31
	.20	7 6	41 31	12	9   7   	18	14  12  	6	5   3	18 12	11 7	18	17
.70	.50	67	160   41	490 134	326 i 85 i	$\begin{array}{c} 735 \\ 201 \end{array}$	494   130	$\begin{array}{c} 351 \\ 92 \end{array}$	561	675 184	449 116	1000	671 178
	.40   .30   .20	28 15 10	16   8   5	30	34  17  11	45	52  26  17	23	25   12   7		53 26 16		82   41   25
	. 10	7	31	14	71	21	11	9	41	18	9	27 	14
.60	.50   .40   .30		147   33   13	130	301  69  28		456  106  43		481 201	688 190 88	101	1000   285   132	570  155  68
	.20	17	71	34 16	16  6		25   10	22 14	91 51	44 28	20 12	66	32   19
.50	.40   .30	266 67	 120  27	$\begin{array}{c} 532 \\ 134 \end{array}$	1 247   58	201	·   376   89	377	170 371	6 <b>88</b> 1 <b>84</b>		1000	469   122
	.20 .10	<b>28</b> 13	10  4	26	22   9   	39	35   14   	17			<b>29</b> 11	$\begin{array}{c} 111 \\ 51 \end{array}$	45   19
. 40	.30 .20		86   17	490		735		35 1 80	1231	$675 \\ 160$		1000 240	370 81
0.0	.10	20	51				18 I	29	71	58		87	261
.30	.20   .10	200 41	501 81 1	400 82	105   18   		1621 291			$\begin{array}{c} 570 \\ 114 \end{array}$	150 25	855 171	2311 401
.20	.10	135	20	270		405	68   	190 		380	61	570	96 i i

VALUES OF n.M FOR SELECTING. WITH P(CS) >= P*, A SUBSET OF k = 3 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STANE				P* =	.90		ł	-		P* =	.95		
PROPOF	LOWER	n	M		M				M		M	n	M
.90	.80   .70   .60   .50   .40   .30   .20   .10	169 51 25 17 11 7 6 3	 42  20  13  5  4  2	$338 \\ 102 \\ 50 \\ 34 \\ 22 \\ 14 \\ 12 \\ 6$	294  86  41  27  17  10  9  4	153 75 51 33 21 18	4441 1311 631 421 261 161 141	10 8	 193  56  27  16  11  7  5  3		391 115 56 33 23 15 11	204 102 63 45 30 24	591  174  85  51  36  23  18  11
. 80	.70 .60 .50 .40 .30 .20 .10		188  50  23  13  8  4  3	140 68 40 26 14	382   103   48   27   17   8   7	210 102 60 39 21	578  157  74  42  26  13  11	94 43 27 17 11	254   67   29   17   10   6   4	188 86 54 34	512 138 61 37 22 13 9	129 81 51 33	773  211  93  57  34  21  15
.70	.60 .50 .40 .30 .20	305 82 37 19 13 7	199   50   21   10   6   3	26	406   104   45   21   14   7	246 111 57 39	615  159  69  33  22  11	107 48 27 17	270  65  27  14  8  4	214 96 54 34	469 135 57 30 18 9	144 81 51	669  207  89  48  29  16
.60	.50 .40 .30 .20 .10	328 81 37 20 11	181   41   17   8   4	162 74 40	371  86  37  18  9	243 111 60	562 132 57 29 15	48 27	246 56 22 11 51	222 96 54	406 118 47 25 12	144 81	567  181  74  39  20
.50	. 40 . 30 . 20 . 10	328 82 34 17	148 33 12 5	164 68	305 70 27 12	$\begin{array}{c} 246 \\ 102 \end{array}$	463   109   42   19	107 43	201  43  15  6	214 86	92 33 14	129	466 142 52 23
. 40	.30 .20 .10	305 70 25	107 21 6	140	222 46 14	210	339 71 22	94	145   28   8	188 68	$\begin{array}{c} 255 \\ 61 \end{array}$	1000	367  95  30
.30	.20 .10	249 51	62 10		131 22		201 36		84 13	668		1000 204	270 48
.20	. 10	169	25	338	54	507	85	225	33	450	72	675	113

67

0

#### VALUES OF n, M FOR SELECTINC, WITH P(CS) >= P*, A SUBSET OF k = 4 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STAND	ARD			P* =	.90					P* =	.95		1
	LOWER		M		M	n	M		M		M	n	M
.90		57 29 17 12 9 6	47  23  13  9  6  4	$     \begin{array}{r}       1  14 \\       58 \\       34 \\       24 \\       18 \\       12 \\       10 \\       10 \\       \end{array} $	96 47 27 18 13 9	87 51 36 27 18 15	146   73   4 1	38	641 301 181	76 48	132 62 38	114	661  200  95  59  36  28  18  11
. 80	.60   .50   .40	37	212  55  25  14  9	562 154 74 44 30 18 12	431 113 52 30 20 11 7	843 231	173   80   46   31   17   11	104	741	687 208 98	153	16 1	771  233  106  63  34  21  15
.70	.60   .50   .40   .30   .20	348 92 44 23	227   56   25   12   7	674 184 88 46 30 18	448 117 53 26 16 9	1000 276 132	672 178 82 41 25 14	457 120 55 29 17 12	298  73  31  15	728 240 110 58 34 24	152 66 33	1000 360 165 87 51 36	667  232  102  51  28  19
. 60	.50   .40	377 93 44		688 186 88 44 24	388 99 44	1000 279 132 66 36	570 151 68	495 123 55 30 15	273	747 246 110 60 30	418 130 54	1000 369 165 90 45	565 200 85 44 20
. 50		92 37		688 184 74 34	319 79 29 11	$1000 \\ 276 \\ 111 \\ 51$	469   122   45   19	495 120 49 24	223   48   17   7	747 240 98 48	343 103	1000 360 147 72	465   159   60   27
.40		$\substack{\textbf{348}\\\textbf{77}}$	122  23  7	$674 \\ 154 \\ 58$	245   50   16	1000 231 87	370   78   26	457	160  31  9	728	262 68 21	1000 312	366   106   34
. 30		281 57	701	$\begin{array}{c} 562 \\ 114 \end{array}$	148 25	843 171	227 40	374 78	93 15	687 156	180	$\begin{array}{c} 1000 \\ 234 \end{array}$	268 55
.20	.10   	190		380	61	570	96	252	37	504			127

0

**VALUES OF n, M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 5 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)** 

GULAND	1			P* =	.90		!			P* =	.95		l
STAND PROPOR UPPER		n	M	n	<u>M</u>	n		n	M		M	n	M I
.90	 .80   .70   .60   .50   .40   .30   .20   .10	$210 \\ 62 \\ 33 \\ 20 \\ 14 \\ 10 \\ 6 \\ 5$	 180  51  26  15  10  7  4  3		365 104 54 32 22 15 8 7	186 99 60 42 30 18	551  159  83  49  33  23  13  11	83 42 25 18 12 9	 228  68  33  19  13  8  6  3	166 84 50 36 24 18	462  140  69  40  28  18  13  6	249 126 75 54 36 27	698  213  105  61  43  28  20  10
.80	.70   .60   .50   .40   .30   .20   .10	87 40	233   62   27   16   9   5   3	174 80 50 30	474 128 56 34 19 11	261 120 75 45 27	716 195 87 53 30 17 11	52 30 20 13	791	40 26 18	536 163 73 40 26 16 10	156 90 60 39	770  249  113  63  40  25  16
.70	.60   .50   .40   .30   .20   .10	377 102 46 25 15 10	246  62  26  13  7  4	204 92 50	129	1000 306 138 75 45 30	670   198   85   44   25   16	57 31 20 12	317	743 260 114 62 40 24	165	171 93 60 36	6666 252 1061 551 341 191
.60	.50   .40   .30   .20   .10	46	229  52  21  10  5	50	398	1000 309 138 75	•	535 133 57 30	295 i 67 i	$767 \\ 266 \\ 114 \\ 60$	429	1000 399 171 90	564  217  88  43  24
. 50	.40 .30 .20 .10	415 102 40 20	187   41   14   6	204 80	87	$1000 \\ 306 \\ 120 \\ 60$	468 135 49 22	130 52	241  52  18  7	$\frac{260}{104}$	111	156	463 172 64 28
. 40	.30 .20 .10	377 87 33	132   26   8	174			369 88 30	$\begin{array}{c}111\\42\end{array}$	170   33   10	84	72	1000 333 126	364 113 38
.30	.20	309 62	77 12			927		402	100		182 36	1000	267 58
.20	.10	210	31	420	68	630	106	266	39	532	85	798	134

#### VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 6 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

				P* =	.90		1			P* =	. 95		1
STANI PROPOH	RTIONS						1						1
UPPER	LOWER	n	M		M 	n	M	n	M	n	M	n	M I
.90	. 80	224	  192	448	389	672	5881	286	245 I	572	497	-   858	751
. 90	.70		561			204	174	88		176	148		2251
	.60		271			102	85		361		75		1151
	.50 .40	21   15	161	42 30	33		51 361		21	56 36	45 28		681
	.30	10	111 71 41	20	15	30	23	18 13	13   9	26	19	39	43   30
	.20	-	41	12	8 7	18	13	9	61	18 14	13		201
	. 10	5	31		7		111		41	14	9	21	15
.80		333		666	511		772	426		713		1000	7691
	.60 .50		671 291		139 61		211	$\begin{array}{r}118\\55\end{array}$		$\begin{array}{c} 236 \\ 110 \end{array}$	174	354   165	265
	.40		161	50	34	75	521	32	201	64	43		671
	.30		101	34	22	51	34	22	13	44	28		45
	.20		61 31		13 6	33   18	211		71		16 10		25   16
	. 10				U	10	111		1		10		101
.70		409	2671			1000				760		1000	6651
		107 48	65   27		135		2071	$\begin{array}{r} 135 \\ 62 \end{array}$	82	270		405   186	261
	.40	27	141	54	31	144 81	89   48	33	821 351 171	66	37	99	581
	.20		8	34	18	51	291	22	101	44	23	66	37   20
	.10	10	4:1 I	20	10	30	16	13	51		12		201
. 60	. 50	444	245 I			1000		566		783		1000	563
		109	551			327	1771			278	147		2261
	.30		221		47	144	74   36	$\begin{array}{c} 62 \\ 32 \end{array}$	281	124 64		186	961 461
	. 10		5		12	45	201	18	61	36	15		241
.50	.40	444	200		3331		4671	566	1	783	358	1000	462
.00			431	214	92	321	1421	135	541	270		405	1791
	.20		151	86	33	129	531	55	19	110		165	671
	.10	21	61			63			81		19	84	31
.40		409	143 i	704	254	1000	367	520	182	760		1000	3631
		94	281			282	961			236	77		120
	.10	34	81		19	102	31		11		201	138	421
.30	.20	333	831	666	175	999	2691	426				1000	2661
	. 10	68	131		30		481		17		39		621
.20	. 10	_224		448		672	113			572		858	144
							1						!

#### Table 30

#### VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 7 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

GRAND				P* =	.90		!			P* =	.95		I
STAND PROPOR UPPER	TIONSI		M		M	n	M		M		M	n	M
.90	.80 .70 .60 .50 .40 .30 .20 .10	37	 204  60  29  16  11  3  3		414 123 61 33 23 15 11 7	219 111 63 45 30 24	625  187  93  51  36  23  18  11	89 46 28 18 13 10 7	 257  73  36  21  13  9  6  4	178 92 56 36 26	521 150 75 44 27 19 14 9	267 138 84 54 39 30	 787  228  115  68  43  30  22  15
. 80	.70 .60 .50 .40 .30 .20 .10	46 27 17 11	267  71  31  17  10  6  4	200 92 54 34 22 16	147	138 81 51 33 24	772   225   100   57   34	446 125 58 35 22 13 10	 336  89  39  22  13  7  5	250 116 70 44 26 20	184 82	174 105 66 39 30	769 281 126 74 44 25 18
.70	.60 .50 .40 .30 .20 .10	434 112 53 27 17 10	283 68 30 14 8 4	717 224 106 54 34 20	475 142	1000 336 159 81 51 30		543 145 64 35 22 13	354   88	771 290 128 70 44 26	508 184 77	1000 435 192 105 66 39	664 281 119 62 37 20
.60	.50 .40 .30 .20 .10	53 27	257  59  24  11  5	733 234 106 54	<b>411</b> 124	1000 351 159 81		$595 \\ 147 \\ 64 \\ 35$	328  74  29  14  6	797 294 128 70 36	444 156 63	1000 441 192 105 54	562  239  98  51  24
.50	.40 .30 .20 .10	466 112 46 21	210  45  16  6	224 92	96			28	268 58	797 290 116 56	364 124	1000 435 174 84	461 192 71 31
. 40	.30 .20 .10	100	152  30  9	$717 \\ 200 \\ 74$	$\begin{array}{r} 258 \\ 65 \end{array}$	1000 300 111		$\begin{array}{c} 543 \\ 125 \end{array}$		$\begin{array}{c} 771 \\ 250 \end{array}$	$\begin{array}{c} 275 \\ 81 \end{array}$	1000 375 138	362 127 41
.30	.20 .10	354 73	88 14	677	177	1000 219	269   51	446 89	111			$\begin{array}{c}1000\\267\end{array}$	265   62
.20	. 10	238	35	476	77			300		600		900	151

VALUES OF n, M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 8 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STAND				P* =	.90		l			P* =	.95		1
	LOWER		M	n	M		N		M		M	n	
.90	$\begin{array}{c} .80\\ .70\\ .60\\ .50\\ .40\\ .30\\ .20\\ .10\\ \end{array}$	38	 210  60  30  18  11  7  5  3	146 76 48 30 20 16	426 123 62 38 23 15 11 7	114 72 45 30 24 15	643  187  95  36  23  18  11	94 47 28 21 15 10 7	263  77  37  21  15  10  6  4	94 56 42 30 20	533 158 77 44 32 22 14 9	282 141 84 63 45 30 21	805  241  117  68  50  35  221 15
. 80	.70 .60 .50 .40 .30 .20 .10	49 30 17 11	279  72  33  19  10  6  4	202 98 60 34 22 16	524 149	1009 303 147 90 51		466 128 61 35 22	351  91  41  22  13  8  5	122 70 44	559	1000 384 183 105 66 45	768 287 132 73 44 29 18
.70	.60 .50 .40 .30 .20 .10	55	296  71  31  15  8  4	727 234 110 58 34	148 66 33	165 87 51 30	668 226 102 51 28 15	566 150 66 37 22 15	369  91  37  19  10  6	132 74 44 30	190	198 111 66 45	664  290  122  65  37  24
.60				$\begin{array}{c} 242 \\ 110 \end{array}$	418 128	1000 363 165 90		$615 \\ 153 \\ 66 \\ 35$	339 i 77 i	807 306 132	449 162	1000 459 198	561  249  102  50  28
. 50	.40 .30 .20 .10	49	223   47   17   7	234 98	100	$1000 \\ 351 \\ 147 \\ 72$	465   155   60   27	61	601	122	128		461 1991 751 311
.40	.30 .20 .10	454 101 38	159   30   9	202	65	$1000 \\ 303 \\ 114$	366   102   34	47			279   83	1000 384 141	362 130 42
.30	.20 .10	370 73	921	146	179	$\begin{array}{c} 1000\\ 219 \end{array}$		466 94	116 18			1000	264   66
. 20	. 10	245		490		735		307	45	614	99	921	155   

#### VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 9 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STAND				P* =	.90					P* =	. 95		
PROPOR	TIONS						i						ł
UPPER	LOWERI	n	M	n 	M	n	M	n	M		M	n	M
.90	.80	259	222	518	450	777	ا 680 ا	321	 275	642	558	963	 842
. 90	.70	78	64	156	131		2001	99	81	198	167		254
	.60	38	301	76	62		951		40		83		1281
	.50	24 17	18   12	48 34	38 26		59 I 41 I		23   15	62 42	49   32		76   50
	.30		8		18		28		10		22		35
	.20	8	51	16	11	24	181		71		16		25
	. 10	5	31	10	6		101	7	41	14	9	21	15
.80		386	291		530	1000	771		361			1000	767 1
	.60 I .50 I	108	771		159 74		2421		96   42	270 126	199   89		303   137
	.50	52 30	35		41		631		221	70	47		731
	.30	19	iii		24		381	24	14	48	31		491
	.20	13	71		16		25		8		18		291
	. 10	8	41		9		141	11	51	22	12		20
.70	.60 i	469	306 i			1000	6671		3821			1000	6631
	.50		741		154		2361		941		196		300
	.40   .30	55 31	31		66 35		1021		391		84 42		130  65
	.20	19	91		20		321		iíi		25		401
	. 10	12	51	24	12		19	15	6	30	14	45	23
.60	.50	515	284	757		1000	565	635		817		1000	561
	.40	127	64		135		2071		791		166		2561
	.30	55 30	25   12		54 27		85 I 43 I		32	140 70	69 32		108  50
	. 10		6		14		23		7		17		28
. 50	.40	515	2321	757	347	   1000	464	635	286	817	372	1000	460 I
	.30	122	491		104	366	1611		621	310	133		205 I
	.20		18		40		641		221		49		771
	. 10	24	71	48	16	72	26	31	91	<b>62</b> ,	21	93	34 I I
.40	. 30	469	164			1000	365		205			1000	361
	.20	108	321			324	110		401		88 29	405 153	1371
	. 10	38 	91		21	114 	34	91	121	102	29	100	401
.30	.20	386	96 İ	693		1000	2671		119			1000	2641
	. 10	78	15	156	34	234 	55	99	191	198	43	297	701
. 20	. 10	259	38	518	83	777	131	321	47	642	103	963	162

VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 10 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STANI	ARD			P* =	.90					P* =	.95		ł
PROPOR	LOWER		M	n	M	n	M	n	M	n	M	n	MI
.90	.70	266 83 42 25 18 12 8 5	68  33  19  13  8  5	84 50 36 24 16	462 140 69 40 28 18 11 6	249   126   75   54   36   24   15	213 105 61 43	51 32 21 15 11 7	82   40   24   15	656 200 102 64 42	570 168 83 51 32 22 16 9	300   153   96   63   45   33   21	8611 2561 1271 781 501 351 251 151
. 80	.60 .50 .40 .30 .20	398 111 52 30 20 13 8	79  35  19  12	222 104 60 40	534 163 73 40 26	1000 333 156 90	770 249 113 63 40	491 135 64 38 24	96   43   24   14   8   5	745 270 128 76 48 30 22	567 199 90 51 31	1000   405   192   114   72   45   33	767   303   139   80   48   29   20
.70	.50 .40 .30 .20	483	315   77   32   16   9	741 254 114 62 40 24	490 161 68 35 21	1000   381   171   93   60   36	666   246   106   55   34	603 155 73 39 24 15	393   94   41   20   11	801 310 146 78 48 30	527 196 88 44 25 14	1000 465 219 117 72	662  300  136  69  40  23
.60		57 30	290   66	763 262 114 60	426 139 56 27	1000 393 171	564 213 88	655 163 73 38 21	361 821 331	$827 \\ 326 \\ 146$	460 173 72 35	1000 489 219 114 63	560 265 113 55 28
. 50			511	$254 \\ 104 \\ 50$	109 40	1000 381 156 75	464 168 64 28	655 155 64 32	621	827 310 128 64	377 132 50	1000	459   205   78   35
. 40				741 222 84	72 23	1000 333 126		603 135		102	88	153	360  137  46
. 30	.20 .10	398 83	991	699 166	182 36	1000 249	2671	491 100	122	745	192	1000	263 70
. 20	. 10	266		532		798		328		656	105	984	165

#### VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 11 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STANI	) ARD			P* =	.90					P* =	.95		1
	LOWER		M		M		M I	n	M		M	n	<u>M</u>
.90	.80 .70 .60 .50 .40 .30 .20 .10	42 25 18	 234  69  33  19  13  13  8  6  3	168 84 50 36 24 18	474 142 69 40 28 18 13 6	252 126 75 54 36 27	215   105   61   43	51 32 21 15 11	 287  82  40  24  15  10  7  4	667 200 102 64 42 30 22	579 168 83 51 32 22 16 9	153 96 63 45 33	 875  256  127  78  50  35  25  15
. 80	.60 .50	410 114 55 30 21 13 9	309  81  37  19  12  7  4	228 110 60 42 26 18	168	63 39 27	770  256  120  63  43  25  16	66 38 24 15	379   100   44   24   14   8   5	132 76 48 30 22	208	198 114 72 45 33	767  316  143  80  48  29  20
.70	.60 .50 .40 .30 .20 .10	503 132 61 33 21 12	328  80  34  17  10  5	751 264 122 66 42	496 167	1000 396 183 99 63 36	6666 256 113 58 35 19	73 39 24	401   97	807 320 146 78 48 30	531 202 87	1000 480 219 117 72 45	662  310  135  69  40  23
.60	.40	546 135 61 30 18	301  68  28  12  6	270 122 60	<b>432</b> 143	1000 405 183 90	564   220   94   43   24	73 38	371 841	$836 \\ 334 \\ 146 \\ 76$	465 177 72	1000 501 219 114	559  272  112  55  28
. 50	.40 .30 .20 .10	546 132 55 25	246  53  19  7	264 110	113 43	1000 396 165 75	463   175   67   27	66	641	836 320 132 64	137		459   212   81   35
.40	.30 .20 .10	503 114 42	176 341 101	228	74	1000 342 126	364   116   38		215   42	807 282 102	287 92	1000 423 153	360  143  46
.30	.20 .10	410 84	102 16		183	1000 252		503 100	125   19		193	1000 300	263   70
. 20	. 10	273	401	546	88	819	137	335	49	667	107	1000	168

VALUES OF n, M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 12 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

OTAND	400			P* =	.90		!			P* =	.95		1
STAND PROPOR	TIONS								26				
UPPER	LOWER	n			M	n	M	n	M	n	M	n	M
.90	.80 .70	286 84	245   69	168	141	858 252	215		86		177		874   269
	.60   .50   .40   .30	28 18	34   21   13   79	56 36	70 (45) 28 19	54	107 69 43	32	43   24   15   10	42	90 51 32 22	96 63	138  78  50  35
	.20		6  3	18	13		20 10	11	71	22 14	15 9	33	25   15
. 80	.70   .60   .50   .40   .30   .20   .10	$55 \\ 32 \\ 21$	318  84  37  20  12  7  4	236 110 64 42 26 18	174	63 39	769 265 119 67 42 25 16	69 40 24 15 11	388  101  46  25  14  8  5	138 80 48 30 22	209	207 120 72 45 33	766  319  150  84  48  28  20
.70	.60 .50 .40 .30 .20 .10	62 33 21	337   82   35   17   10   5	758 270 124 66 42		99 63 39	665 261 115 58 35	629 165 75 41 24 15		814 330 150 82 48 30	535 209 90	1000 495 225 123 72 45	661 319 139 72 40 23
.60	.50 .40 .30 .20 .10	62	311 i 70 i	278 124	436 147 61 29	1000 417 186	563   226   96	686 169 75	378   85	843 338 150	468	1000 507 225 120	559  275  116  58  27
. 50	. 40 . 30 . 20 . 10	564 135 55 28	254  54  19  8	270 110	116	84	1791	69 32	661		383 141 54 22	207	458 218 85 35
.40	.30 .20 .10		181 35   10	758 236 86	271 77	$1000 \\ 354 \\ 129$		629 142 55	421	814 284 110	921	1000 426 165	359  144  50
.30	.20	422 84	105		185	$\begin{array}{c} 1000 \\ 252 \end{array}$		515		$\begin{array}{c} 757 \\ 210 \end{array}$	194   46	1000 315	262 74
. 20	.10	286	42	572		858	144   	348	51	674	108	1000	167

#### VALUES OF n, M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 13 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

PROPORTIONSI         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         n         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N <t< th=""><th>STAN</th><th>DARD I</th><th></th><th></th><th>P* =</th><th>.90</th><th></th><th></th><th></th><th></th><th>P* =</th><th>.95</th><th></th><th>1</th></t<>	STAN	DARD I			P* =	.90					P* =	.95		1
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	PROPOR	RTIONS		M		M	n	і Мі		M		M	n	MI
.60       46       361       92       751       138       1151       55       431       110       901       165       138         .60       18       131       36       28       54       431       21       151       42       32       63       50         .30       13       9       26       19       39       301       15       101       30       221       45       34         .20       10       61       20       141       30       231       17       763       580       1000       7661         .60       118       841       236       174       354       2651       145       1031       290       213       435       3251         .50       58       391       16       821       174       1261       69       461       138       97       207       1501         .40       35       221       70       481       105       74       40       461       318       77       24       144       48       31       72       461       20       13       7       26       163       39       251       179       3	.90	.80	293	251				769		 304	677	588	1000	874
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$														
.40       18       13       9       26       19       39       30       15       10       30       22       45       34         .20       10       6       20       14       30       23       11       7       22       45       34         .10       7       4       14       9       21       15       7       4       14       9       21       15         .80       .70       434       327       717       547       1000       769       527       397       763       580       10000       766         .60       118       84       236       174       354       265       145       103       290       213       435       325         .50       58       39       116       821       174       126       66       451       24       144       483       172       481         .30       22       13       442       26       11       30       181       11       5       22       12       33       21       51       33         .10       10       526       433       763       503       100 <th></th> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>														
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$								431	32					
$\begin{array}{c c c c c c c c c c c c c c c c c c c $			13	- 10	26		39	301	15		30	22	45	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $										71	22	15	33	241
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		.10	7		14	91				41	14	9	21	15
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	. 80			3271	717	547	1000	7691	527	3971		580	1000	766
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$														
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$			35	221	70	48	105			251	80			841
$\begin{array}{c c c c c c c c c c c c c c c c c c c $			22	13	44	28	66		24	141	48			<b>48</b>
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$				71	26				17	91	34			
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		. 10	10			11	30							20
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	.70			<b>34</b> 3 i	763			665 i	646	421	823	541	1000	661
$\begin{array}{c c c c c c c c c c c c c c c c c c c $									170					
$\begin{array}{c c c c c c c c c c c c c c c c c c c $				171	120	37	192		41					
$\begin{array}{c c c c c c c c c c c c c c c c c c c $			22	101	44	23	66	371	24					
$\begin{array}{c c c c c c c c c c c c c c c c c c c $			13	5	26	12	39	20	15	6	30	14	45	23
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	.60			3171	787							473	1000	559
$\begin{array}{c c c c c c c c c c c c c c c c c c c $							429	2331	173				519	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$							192	991	40					
$\begin{array}{c c c c c c c c c c c c c c c c c c c $								24	21		42	17	63	27
.40 .30   526 184  763 273   1000 363   646 226   823 292   1000 359   .40 .30   526 184  763 273   1000 363   646 226   823 292   1000 359   .20   118 35   236 76   354 120   145 43   290 94   435 147   .10   46 11   92 26   138 42   55 13   110 31   165 50   .30 .20   434 108   717 186   1000 265   527 131   763 196   1000 262   .10   89 17   178 39   267 62   105 20   210 46   315 73	.50	.40	575	259 I				462	704			387	1000	458
.10       28       8       56       19       84       31       32       9       64       21       96       35         .40       .30       526       184       763       273       1000       363       646       226       823       292       1000       359         .20       118       35       236       76       354       120       145       43       290       94       435       147         .10       46       11       92       26       138       42       55       13       110       31       165       50         .30       .20       434       108       717       186       1000       265       527       131       763       196       1000       262         .10       89       17       178       39       267       62       105       20       210       46       315       73					280	120	420	185	170					2251
.40       .30       526       1841       763       273       1000       363       646       226       823       292       1000       359         .20       118       351       236       761       354       120       145       431       290       941       435       147         .10       46       111       92       261       138       421       55       131       110       311       165       50         .30       .20       434       1081       717       186       1000       265       527       1311       763       196       1000       262         .10       89       17       178       39       267       62       105       20       210       461       315       73						45	174	71	69					841
.20       118       35       236       76       354       120       145       43       290       94       435       147         .10       46       11       92       26       138       42       55       13       110       31       165       50         .30       .20       434       108       717       186       1000       265       527       131       763       196       1000       262         .10       89       17       178       39       267       62       105       20       210       46       315       73		. 10	28							91		21	90	301
.10   46 11  92 26  138 42  55 13  110 31  165 50  .30 .20   434 108  717 186 1000 265  527 131  763 196 1000 262  .10   89 17  178 39  267 62  105 20  210 46  315 73	. 40													3591
.30 .20   434 108  717 186 1000 265  527 131  763 196 1000 262  .10   89 17  178 39  267 62  105 20  210 46  315 73														
.10   89 17  178 39  267 62  105 20  210 46  315 73				i				1		1			1	1
	. 30					186	1000							
		. 10	89	17	178									73
	. 20	. 10	293	43	586	94	879							167

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	ARD			P* =	.90					P* =	.95		
	TIONS   LOWER		M		M	n	M	n	M		M	n	M
.90	.50	89	73  36  21	92 56 36 20 14	150 75 44 27 19 14 9	897	2221	$362 \\ 110 \\ 55 \\ 32 \\ 21 \\ 15 \\ 11 \\ 7$	001	681 220	1.95	1000 330 165 96 63 45 33 21	874  282  137  50  34  24  15  765
. 80	.70	442	333	721	550	$   \begin{array}{r}     1000 \\     363 \\     174 \\     105 \\     66 \\     39 \\     30 \\     1000 \\   \end{array} $							
.70	50 1	040	85   36   18   10   5	280	177 77 39 23 12	420	271  119  62  37  20	000	103  43  21  12  6	827 340 154 82 52 30	215 92 46 27 14	510 231 123 78 45	3201
. 60	.50	586	323	793 290 128 70 36	442	1000 435 192 105 54	562	715 177 77 40 21	394	857 354 154 80 42	475	1000 531 231 120 63	558  288  118  57  27
. 50	.40 .30 .20 .10	$586 \\ 140 \\ 58 \\ 28$	2641	793	362	1000 420 174 84	462	715	322	857	389	1000	458
. 40	.30   .20   .10	$\begin{array}{c} 543 \\ 121 \end{array}$	1901 361	$\begin{array}{c} 771 \\ 242 \end{array}$	275   78	1000 363 138	362   123	$\begin{array}{c} 655 \\ 149 \end{array}$	2291	827 298	293 97	1000 447	3591
.30	.20	442	1101	721	187	$\begin{array}{r}1000\\267\end{array}$	2651	535	1331	767	197	1000	2621
.20	.10	299	44	598	96	897	151  	362		681	109	1000	167

#### VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 14 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

Table 38

VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 15 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STAND	ARD I			P* =	.90					P* =	.95		1
PROPOR UPPER			M	n	M	n		n	M	n	M	n	MI
.90	.80	300	257 I	600	521		 787			684		   1000	 874
	.70 1	94	771	188	158		241		911		187		2841
	.60	47	371	94	77		118		441		91		1401
	.50	28 18	21	56 36	44 ( 27 (		681 431		261		55 37		85   57
	.30	13	91	26	19		301		111		24		371
	.20	10	61	20	14		221		71	22	15		241
	.10	7	41		9		15		41		9		15
. 80		454	342	727		1000		547		773		1000	765
	.60   .50		89   40	250 120	184	375 180	280   130		108   48		224 102		3411 1561
	.50		22		47		731		251			120	841
	.30	22	131	44	28		441		151	52	33		521
	.20 1		81		18		291		91	34	20		331
	.10	10	51		11		18	11	51	22	12	33	201
.70	.60	549	358		510	1000		669		834		1000	660
	.50		881	290	184		281		1061		221	525   240	339   148
	.40   .30	64 35	361 181 101	128 70		192   105	62		45   22			129	76
	.20	22	101	44	23		371		12		27		431
	.10	13	51		12	39	201	16	6		15	48	25
.60		597	329			1000		726		863		1000	558
	.40	149	751	298		447	243			358		537	2911
	.30	64 35	29   14	128 70		192   105	981 511		36   16	160 80	79	240   120	123   57
	.20	18	61	36	14		23		8		20		32
. 50	.40	597	269			1000	461	726		863		1000	457 I
	.30	145	581	290		435	1921		701			525	2321
	.20	60	211			180	741		25			216	881
	. 10	28	81	56	19	84 	311	35	101	70	24	105 	39   
. 40	.30 i	549	1921	774		1000	3621	669		834		1000	3581
	.20 1	125	371			375	127		45		99		1541
	.10	47	11	94	26	141 	421		131		31	168 	50  
.30	.20 i	454	113	727		1000	265	547		773	198	1000	261
	. 10	94	181	188	41	282	661	111	211	222	49	<b>33</b> 3 	781
.20	. 10	300		600	96	900	151	368		684	109	1000	166

STAN	DARD   RTIONS			P* =	.90					P* =	.95		1
	LOWER		M		M		N	n	M		M	n	Mi
.90		94 47 28 18 13 10	 263   77   37   21   13   9   6   4	94 56 36 26 20 14	534 158 77 44 27 19 14 9	141 84 54 39 30 21	806   241   117   68   43   30   22   15	56 35 24 18 11 7	911	112 70 48 36 22 14		105 72 54 33 21	873   284   140   85   57   42   24   14
.80	.60	15	348  91  41  22  13  8  5	731 256 122 70 44 30 20	557 188	1000 384 183 105 105 66 45 30		555 152 72 43 26 17 11		777 304 144 86 52 34 22		1000 456 216 129 78 51 33	765 341 156 90 52 32 20
.70		$\begin{array}{c} 35\\22\end{array}$	367  88  37  18  10  5	781 290 132 70 44 26	515 183 79	1000   435   198   105   66   39	664	675 175 82 43 26 18	440   106	837 350 164 86 52 36	549 221 98	1000 525 246 129 78 54	660  338  152  76  43  28
.60	.40 .30 .20			806 302 132 70 36	449 160 65 32	1000   453   198   105   54	561 246 102 50 23	737 183 82 43 24	406   92	868 366 164 86 48	481 194 81	1000 549 246 129 72	557 298 126 62 32
. 50		613 145 61	276 58 21 8	806 290 122	124 47	1000 435 183 84	461 192 75 31	737 175 72 35	332   70   25   10	868 350 144 70	394 150 56	1000 525	457   231   88   39
. 40	.30 .20 .10		197   38   11	256	279 83 26	1000 384 141	362 130 42	$\begin{array}{c} 675 \\ 152 \end{array}$		$837 \\ 304 \\ 112$	99	1000 456 168	358 154 50
.30	.20 .10	462 94	181	731 188	189	1000 282	264   66		138 21	777 222	48	$\begin{array}{c}1000\\333\end{array}$	261 78
.20	. 10	307	45   	614	99	921	155   	369	54   	684	109	1000	166

#### VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 16 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

Table 40

**VALUES OF** n.M FOR SELECTING, WITH  $P(CS) \ge P*$ , A SUBSET OF k = 17 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STANI	ARD			P* =	.90					P* =	.95		
	LOWERI		M		M	n		n 	M	n	M	n	
.90	.80   .70   .60   .50   .40   .20   .10	94 47	269   77   37   23   15   10   7   4	94 62 42 30 22	5461 158 77 49 32 22 16 9	141 93 63 45 33	241  117  76  50  35	$376 \\ 115 \\ 59 \\ 35 \\ 24 \\ 18 \\ 11 \\ 7$	941	688 230 118 70 48 36 22	597 194 96 55 37 27 15 9	$177 \\ 105 \\ 72 \\ 54 \\ 33$	 873  294  148  85  57  42  24  14
. 80	.70   .60   .50   .40   .30   .20   .10	35 22 15	354  91  41  22  13  8  5	256 122 70 44 30 22		105 66 45 33		563 155 75 43 28 17	424   110  50  27  16  9  5	150 86 56 34 22	593 228 106 58 36 20 12	$225 \\ 129 \\ 84 \\ 51 \\ 33$	765  348  163  90  57  32  20
.70	.60   .50   .40   .30   .20   .10		371  91  37  19  10  6	300 132 74 44	516	1000 450 198 111 66 45	663  290  122  65  37  24	689 180 82 43 28 18	449   109   46   22   13   7	844 360 164 86 56 36	554 228 98	$1090 \\ 540 \\ 246 \\ 129 \\ 84 \\ 54$	660  348  152  76  47  28
.60	.50   .40   .30   .20   .10	66 35	344  77  30  14  7]	$\begin{array}{c}132\\70\end{array}$	452 162 65 32	1000 459 198 105 63		$746 \\ 185 \\ 82 \\ 43$	4111	873 370 164 86 48	484 196 81	$   \begin{array}{r}     1000 \\     555 \\     246 \\     129 \\     72   \end{array} $	557  301  126  62  32
.50	.40 .30 .20 .10	61	601	$812 \\ 300 \\ 122 \\ 62$	128		460  198  75  34	180 75 35	3361 721 261	873	396 154 58	$1000 \\ 540 \\ 225 \\ 105$	4571 2381 921 391
. 40	.30 .20 .10		199  38  11	256	279 83	1000 384 141		689 155 59	241 461 14		299 101	$1000 \\ 465 \\ 177$	358 157 53
.30	.20	470 94	117	$\frac{735}{188}$	190	1000 282		$\begin{array}{c} 563 \\ 115 \end{array}$	140 221			$\begin{array}{r}1000\\345\end{array}$	261 81
.20	.10	314	•	628		942		376			109	1000	166

#### VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 18 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

	1			P* =	.90		1			P* =	.95		1
STAND				_			1			_			i
PROPOR													1
UPPER	LOWERI	n	M	n	M	n	MI	n	M	n	M	n	MI
	1		1				1		1			1	
.90	.80	314	269 i	628	546	942	824	383	328 İ	691	599	1000	873
	.70 1		811	198	167	297	2541		951	232	195		2971
	.60		371			141	117		461		96		1471
	.50		23		49		761		271		57		881
	.40	21 15	15   10		32 22		50   35		17  12		37 27		571 421
	.20		71	22	16		25		7		15		24
	.10	7	41	14	9		15		41		19		14
	1	-	1				1	-	Í			i	i
.80	.70	475	3581			1000	768		4301			1000	7641
	.60		941		194		296		113		234		3571
	.50   .40		42   22		89 47		1371		50   27		106	225   129	163   90
	.30	35 24	141		31		49		16		36		561
	.20		- 171		18		29		91		20		321
	.10		51		12		201		51		12		201
		_	I						1			I	1
.70	.60 1	583	380			1000	6631			847		1000	6591
	.50		911			450	290		1091		228		348
	.40   .30		381		42	204	126   65		46   23			246   135	152  79
	.20		111		25		40		13	56	29		47
	.10	15	6		14		231		71	36	17		28
	1		1				I		1				I
.60	.50			816		1000		764		882		1000	5571
	.40		791			471	256		941		198		304
	.30	68 35	31  14			204	105   50		37   17		81 39		1261 621
	.10	21	71			63	281		- 16		19		32
	• • • •		• 1				1		i		17		1
. 50	.40 1		285		372	1000	4601			882	400	1000	<b>456</b> I
	.30		601			450	1981			360	154		2381
	.20		221			189	771		261		58		921
	.10	31	91	62	21		341		101	72	24	108	40
. 40	.30	583	204	791		1000	361			847	300	1000	357
. 10	.20		391			396	134		47		103		161
	.10	47	111			141	421		14	118		177	531
0.0		4775	1101		10.0		0(4)		1401	-	000		0(0)
.30		475 99	118			1000	264   70	$\begin{array}{c} 571 \\ 116 \end{array}$	142   22			1000 348	260   81
	.10	77	191	190	44	291	(0)	110	44	404	91	010	011
.20	. 10	314	46	628	101	942	158	383	<b>5</b> 6	691	110	1000	166
	i						1						I

#### VALUES OF n, M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 19 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

				P* =	.90		ļ			P* =	.95		I
STAND PROPOR UPPER	TIONSI	n	M	n	M	n	M	n	M	n	M	n	M
.90	.80   .70   .60   .50   .40   .30   .20   .10		275   81   40   23   15   10   7   4	642 198 102 62 42 30 22 14	558 167 831 49 32 22 16 9	297 153 93 63 45 33	842  253  128  76  50  35  25  15	116 60 36 24 18 13	3281 951 471 271 171 121 81 51		599 195 98 57 37 27 18 12	180 108 72 54 39	873   297   150   88   57   42   29   19
. 80	.70   .60   .50   .40   .30   .20   .10	483 135 64 35 24 15 11	364  96  43  22  14  8  5	741 270 128 70 48 30 22	565 199 90 471 31 18 12	192 105 72 45 33	767   303   139   73   49   29   20	159 75 43 28 17	436  113  50  27  16  9  6	789 318 150 86 56 34 26	599 234 106 58 36 20 15	225 129 84 51 39	764  357  163  90  56  32  24
.70	.60 .50 .40 .30 .20 .10	589 155 71 37 24 15	384  94  40  19  11  6	794 310 142 74 48 30	523 196	1000 465 213 111 72	663 300 132 65 40 23	185 84 45 28	461  112  47  23  13  7	370 168 90 56		1000 555 252 135 84	659  358  156  79  47  28
.60	.50 .40 .30 .20 .10	644 159 71 35 21	355   80   32   14   7	822 318 142 70 42	168	213 105	560 259 109 50 28	191 84 43	422  96  38  17  8	86 48	489 202 83 39 19	252 129	537  311  129  62  31
. 50	.40 .30 .20 .10		290  62  22  9	822 310 128 62			460  205  78  34	185 75	345   74   26   10	883 370 150	400 158 58 24	225	456  245  92  40
. 40	.30 .20 .10	$589 \\ 135 \\ 51$	206   40   12	270	283 88 28		361 137 46	159	247   47   14	318	302 103 33		357  161  54
. 30	.20 .10	483 99	120 19	741 198	191 43	1000 297	264   69		144   22	789 232	$\begin{array}{r} 201 \\ 51 \end{array}$	1000 348	260   81
.20	. 10	321	471	642	103	963	162	383	56	691	110	1000	166

VALUES OF n.M FOR SELECTING, WITH P(CS) >= P*, A SUBSET OF k = 20 BINOMIAL POPULATIONS WHICH CONTAINS ALL POPULATIONS BETTER THAN AN UPPER STANDARD AND NO POPULATIONS WORSE THAN A LOWER STANDARD (POPULATIONS WITH NO. OF 'SUCCESSES' >= M OUT OF n TRIALS ARE SELECTED)

STANI	ARD			P* =	.90		l			P* =	.95		1
	LOWER		M	n	M	n		<u>n</u>	M	n	M	n	M
.90	.80     .70     .60     .50     .40     .30     .20     .10	$     51 \\     32 \\     21 \\     15 \\     11 $	 281  82  40  24  15  10  7  4	200 102 64 42 30 22	570 168 83 51 32 22 16 9	300 153 96 63 45 33	861 256 128 128 78 50 35 25 15	116 60 36 24 18 13	334  95  47  27  17  12  8  5	232 120 72 48 36 26	602 195 98 57 37 27 18 12	180 108 72 54 39 27	873  297  150  88  57  42  29  19
.80	.70 .60 .50 .40 .30 .20 .10	64 38 24 15	370  96  43  24  14  8  5	270 128 76 48 30	199	$72 \\ 45$	767 303 139 80 48 29 20	78 43 28 19	442  115  52  27  16  10  6	324 156 86 56 38	602	1000 486 234 129 84 57	764  363  169  90  56  37  24
.70	.60 .50 .40 .30 .20 .10	71 39	388 94 40 20 11 6	$310 \\ 142 \\ 78 \\ 48 \\ 30$	196	72	663 300 132 69 40 23	84 45 28 18	466 112 47 23 13 13 7	168 90 56	562 234 101 50 29 17	252 135 84 54	659  358  156  79  47  28
. 60			356  81  32  15  7	823 322 142 76	171 70 35	$1000 \\ 483 \\ 213 \\ 114 \\ 63$	560  262  109  55  28	$777 \\ 193 \\ 84 \\ 43 \\ 24$		386 168 86	492 204 83	1000 579 252 129	556  314  129  62  31
.50	.40 .30 .20 .10	64	291  62  22  9	$\begin{array}{c} 310\\ 128 \end{array}$	133	$1000 \\ 465 \\ 192 \\ 96$		777 185 78 36	741	156	158 61		456  245  96  40
.40	.30 .20 .10	135	208 40 12	270	88	$1000 \\ 403 \\ 153$	361 137 461	$\begin{array}{c} 715 \\ 162 \end{array}$	250 481 141		105	1000 486 180	357 164 54
. 30	.20 .10	491 100	122   19		192	$\begin{array}{c} 1000\\ 300 \end{array}$	263 i 70 i		146 221			$\begin{array}{r}1000\\348\end{array}$	260   81
.20	. 10	328	48	656	106	984		390		695	110	1000	165

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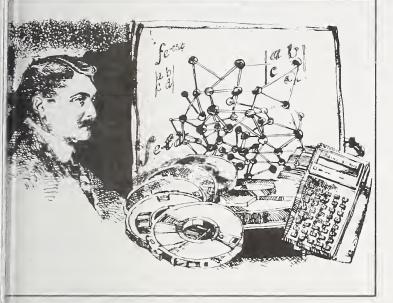
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