Final Report on

QUALITY OF TELEPHONE SERVICE

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EXECUTIVE SUMMARY

The purpose of this research was to study the process of evaluating the quality of telephone service being provided in Ohio, and to recommend a process design that will make effective and efficient use of the personnel and equipment of the Compliance Division of the PUCO. The process design was to be communicated primarily through a procedures manual to be used by the telephone inspector.

The final procedure design was developed to satisfy the organizational objectives of the Compliance Division of the PUCO. Specifically, four such objectives were identified and rank ordered as follows:

1. To provide data and assessment concerning the quality of telephone services to be used as staff input to rate cases.

2. To encourage a regimen of providing good service in the system.

3. To be responsive to public need.

4. To identify incidences of noncompliance with the PUCO Administrative Order 227.

This approach led to a set of inspection procedures aimed primarily at gathering data and assessing the quality of service in metropolitan areas and/or company areas versus the current practice of assessing the quality of service in selected central offices. Furthermore, the individual inspection tasks were separated into homogeneous groupings. The procedures designed to complete each group of tasks were taylored specifically for the group. This will allow the use of an efficient sampling plan and company records with backup inspector checks in order to gain the maximum amount of information about telephone service while using a fixed input of inspector time.

Four documents resulted from the study: this final report; Procedures Manual I for the Subscribers Survey and Collection of Trunk Traffic Data; Procedures Manual II for the Determination of Quality of Telephone Service; and Computer Programs Specification: Quality of Telephone Service Study. Briefly, Procedures Manual I gives the steps the Customer Services personnel should follow when conducting a subscriber survey and/or collecting the trunk traffic data from company records. This is a step that may be done independently from other inspections and will develop information that is useful in planning for the technical inspections. Procedures Manual II delineates the steps for each group of technical inspection tasks as well as steps for planning a metro area inspection. Finally, the Programs Specifications document describes computer programs needed to generate forms and provide analysis of data primarily in support of the tasks laid down in Procedure Manual I.

The procedures include a questionnaire for subscriber surveys that was developed and tested during the study. Computer programs are specified that will provide a thorough statistical analysis of the survey results. The analysis is designed primarily to identify patterns and differences that could be used for screening purposes by identifying exchanges that may require closer scrutiny.

The most significant issue concerned the testing of actual performance relative to the Administrative Order 227 standards for percent of calls completed successfully through the proper switching sequence. The issue was significant because it involved a requirement for capital equipment and great amounts of inspector time. It also involved one of the most objective and quantitative measures of service available. The problem, as outlined in an interim report, is that A.O. 227 specifies percent of completion during the busy hour of the average busy season. While test calling, it is a practical impossibility to also know what the traffic is in order to determine whether the busy hour has occurred. It was determined that for input to rate cases, overall average percentages (busy hour or not) were important and valuable data. Thus, the procedure design for test calling will provide such data. In addition by a slight modification to the test calling sequence, and method of data summary, and by relying more heavily on company traffic studies, good measures of performance during the busy hour can be estimated. These steps are given in Procedures Manual II.

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Introduction

Purpose

The purpose of this research was to study the process of evaluating the quality of telephone service being provided in Ohio, and to recommend a process design that will make effective and efficient use of the personnel and equipment of the Compliance Division of the P.U.C.O. The process design was to be communicated primarily through a procedures manual to be used by the telephone inspectors.

Initial Approach

With well over 1000 central offices in the state it is estimated that using current procedures, even at maximum productivity, would require at least eight years to inspect them all. Thus it was evident that some change in the process was needed in order to reduce the time required for an inspection or to reduce the number of inspections required.

The initial plan that was investigated was to design a very quick inspection that would serve to screen all central offices in order to identify those that required closer scrutiny. To do this a nominal group technique session was organized with the six P.U.C.O. telephone inspectors. As a group they produced a list of 31 criteria that could be checked for screening purposes. Each inspector then ranked the eight criteria he felt were most important and the ranks were summed over the individuals for each criteria. A final set of eight criteria was identified by total rankings. Following the generation of these criteria an experiment was conducted where each inspector was asked to rate hypothetical central offices that had all received varying combinations of appraisals with respect to each of the eight criteria. During this entire process the inspectors expressed concern about their being able to assign any composite rating to a central office even though the appraisal of individual criteria seemed quite feasible. The experimental results bore this concern out by showing that the variance between inspectors was significantly larger than most of the variances resulting from the eight criteria. It was concluded that a practical model could not be built by this methodology

that would reliably screen central offices for further scrutiny.

The Final Approach

The approach finally used was to study the individual steps in the inspection process and to consider:

a. using random sampling techniques,

b. redesigning the steps to require less time to accomplish the same objectives.

The philosophy of random sampling is that one should like to draw inferences about a population if a set of members of that population is carefully selected and somehow measured. Since, as is discussed later, one of the primary functions of these inspections is to supply information concerning quality of service in metropolitan and/or company wide areas, the inspection process was specifically designed to draw inferences about the quality of service being provided in metropolitan areas. They may also be applied to small one-office communities in which case the new procedures become much like the currently used procedures.

In addition to this final report three other documents are being provided to the P.U.C.O.

- Computer Program Specifications is a document which describes two computer programs that will supply partially completed forms for use in customer surveys and trunk traffic data collection efforts. Two other programs are described which accept the data from these completed forms and provide a summary and analysis of the results. Coordination with the Chief of the Data Processing Division of the P.U.C.O. was effected to determine a reasonable means of communicating programming requirements. For each program a purpose is stated, the input and desired output is specified and the mathematical formulas used to create the output are given.

- Procedure Manual I gives the step procedures for conducting the subscriber surveys and gathering the interoffice and E.A.S. trunk traffic data. It includes a tested questionnaire, (see IR2, Appendix) and trunk data collection procedures that were tested on Ohio Bell for the Columbus metro area. These two sets of procedures have been separated from the procedures in Manual II since in working with the Chief of the Compliance Division a plan was devised whereby the newly created Customer Service Section would execute these procedures instead of the technical inspectors.

- Procedure Manual II gives the step procedures to be used by the technical inspectors and their supervisor while inspecting and testing telephone performance in a metropolitan area. These procedures have also been tested in the sense that they will remain technically unchanged from current practice. The major change is in where these inspections occur, how the data is summarized and how the results are interpreted rather than the technical process of performing each individual inspection.

Outline of the Remainder of the Report

The next section will discuss the organizational objectives accomplished by the inspections and how each objective is operationalized. The design strategy used to improve the quality assessment process is discussed and a diagram depicting the information flow and actions required for a metro area inspection is presented.

The third section will review major criteria defined in A0227. Each criteria will be related to the organizational objectives, and the inspection process. Those cases where changes in the criteria would facilitate the inspection process are also discussed.

The final section pertains to implementation of the procedures. It is here that special interpretations and uses of inspection results are given.

The Appendix contains the two interim reports that were submitted during the course of the research. These reports were intended to identify and evaluate alternative courses of action and were used to seek decisions from P.U.C.O. personnel that would affect the final procedure design. In this way an acceptable design is produced to enhance the chances of a successful implementation.

Total System Design

A systems approach was taken to arrive at the final procedures design, thus it was necessary to identify the objectives of the Compliance Division of the P.U.C.O. In the event objectives conflicted and to determine importances of activities the objectives were also ranked. These objectives are listed below and numbered according to their ranking: (Shortened titles in parentheses)

1. To provide data and assessment concerning the quality of telephone services to be used as staff input to rate cases. (Rate)

2. To encourage a regimen of providing good service in the system. (Regimen)

3. To be responsive to public need. (Public)

4. To identify incidences of noncompliance with P.U.C.O. A.O. 227. (227)

The kind of data commonly appearing in staff reports for rate cases are the results of customer complaints, customer surveys and the completion percentages of various types of test calls. These figures are summarized at metropolitan area levels and company totals with very little emphasis on busy hour performance. Since the new procedures are designed to generate this type of data at these levels and to provide professional and experienced assessment of nonquanitatively defined aspects of company performance, then the first objective will be met.

Since the new procedures involve a sampling plan in which each central office, maintenance center, and business office will have a high probability of being visited by a P.U.C.O. inspector each year, the second objective will be met.

The function of the Customer Services section and the P.I.C. are such that the third objective will be met. However, the customer survey and trunk traffic data collection efforts the Customer Services personnel engage in will assist in identifying and verifying public needs. Special technical inspections by the P.U.C.O. inspector may also be used to help satisfy this objective.

The regular inspection procedures have always been technically designed to test and inspect against the specific requirements laid down in AO 227. Therefore, any incidences of noncompliance will be identified and reported as a natural consequence of inspection to accomplish the other objectives. Thus the fourth objective will be met.

Design Strategy

As mentioned earlier the basic design strategy was to orient the inspection procedures towards the inspection of the services being provided

in metropolitan areas. Some of the consequences of this strategy are:

1. Reductions in sample sizes and test calling.

2. Taking advantage of some of the centralized services in a metro area to streamline the inspection process.

3. Outside plant boundaries are ignored.

4. Quality of service is not assessed for central offices except with respect to single or small groups of criteria, however, a complete assessment with respect to all criteria is achieved for the metro area.

5. Elimination of redundancies that would occur if individual offices were thoroughly inspected.

One must recognize that with shifts in populations, changes in their calling habits and seasonal, daily and hourly effects upon the subscriber's need of telephone service, the functioning of any part of telephone system is a dynamic, stochastic process.

The strategies taken to determine a sampling plan under these circumstances were to view the population in different ways depending upon the measure of quality being made. For example, 1) for interoffice trunk performance, a random sample is not used, but a measurement of the performance of the worst case trunks in the system as identified from company data is used, 2) for intraoffice calls, offices are selected randomly and their performance measured using the central office analyzer, 3) similarly for assessment of maintenance programs a visual inspection is performed at randomly selected central offices and a final example, 4) a measurement of trouble reports per 100 lines is made at all maintenance centers, thus one hundred percent sample in this case. Each of these four examples involve a selection of sites and then a measurement of a particular attribute of that site is made. As is the case with all measurements there is error but the procedures are designed to make the error magnitude consistent with the resources available and the objectives of the organization. The main sources of measurement error are listed below and followed by a list of means of providing better control of these errors.

Error sources:

1. Some measurements are made via random or systematic samples at the various sites, therefore random error is a factor.

2. The dynamic aspects of the system introduce error as discussed above.

3. Inspector judgment on qualitative measures is a factor.

4. Clerical error.

Means of control listed in the same order:

1. Aggregation of data in metro areas and further aggregation to assess companies will tend to reduce the impact of these errors since there is no reason to believe these random errors are biased. Further improvement can be achieved by increasing sample sizes in each instance.
2. Since most minimum standards are concerned with performance during peak hours of busy seasons, an attempt should always be made to schedule inspections during the busy season, otherwise the error caused by dynamic characteristics of the system will tend to be biased in favor of the companies. The procedures already incorporate controls for the peak hours. Some improvement could be achieved by increasing the number of days for testing at each site. Inspectors should be aware of and record all unusual current, local events that would have an obvious effect on telephone usage. Finally, two inspectors inspecting a metropolitan area in 30 days is better than six inspectors in ten days since it provides greater opportunity for the dynamic effects to "average out" i.e., the probability that 30 days will be very unusual in terms of telephone usage is lower than the probability that 10 days will be very unusual. Thus spreading the inspections out over time will reduce the probability of getting a bad time sample.
3. The inspectors should meet together at regular intervals to have a peer review of the results of each qualitative inspection. Also, experienced telephone inspectors should be used for these qualitative inspections as is currently the case.
4. Supervisory emphasis of the importance of accuracy should minimize these errors although they will tend to be unbiased and their impact reduced in aggregated data.

One last comment about the time dependent characteristics of the system. The results of this research is a set of procedures which, with the help of Customer Services personnel, will allow two inspectors to cover, as a minimum, the ten largest metropolitan areas in the state each year. Thus a time series of data is obtainable with the six to eight inspectors currently available. After three to five years of such data becomes available a study of this time series should help to better understand these system dynamics. If data is not obtained in each area at least once a year it will obviously take longer to acquire enough data and substantial population or equipment changes could cause some of the earlier data to become irrelevant.

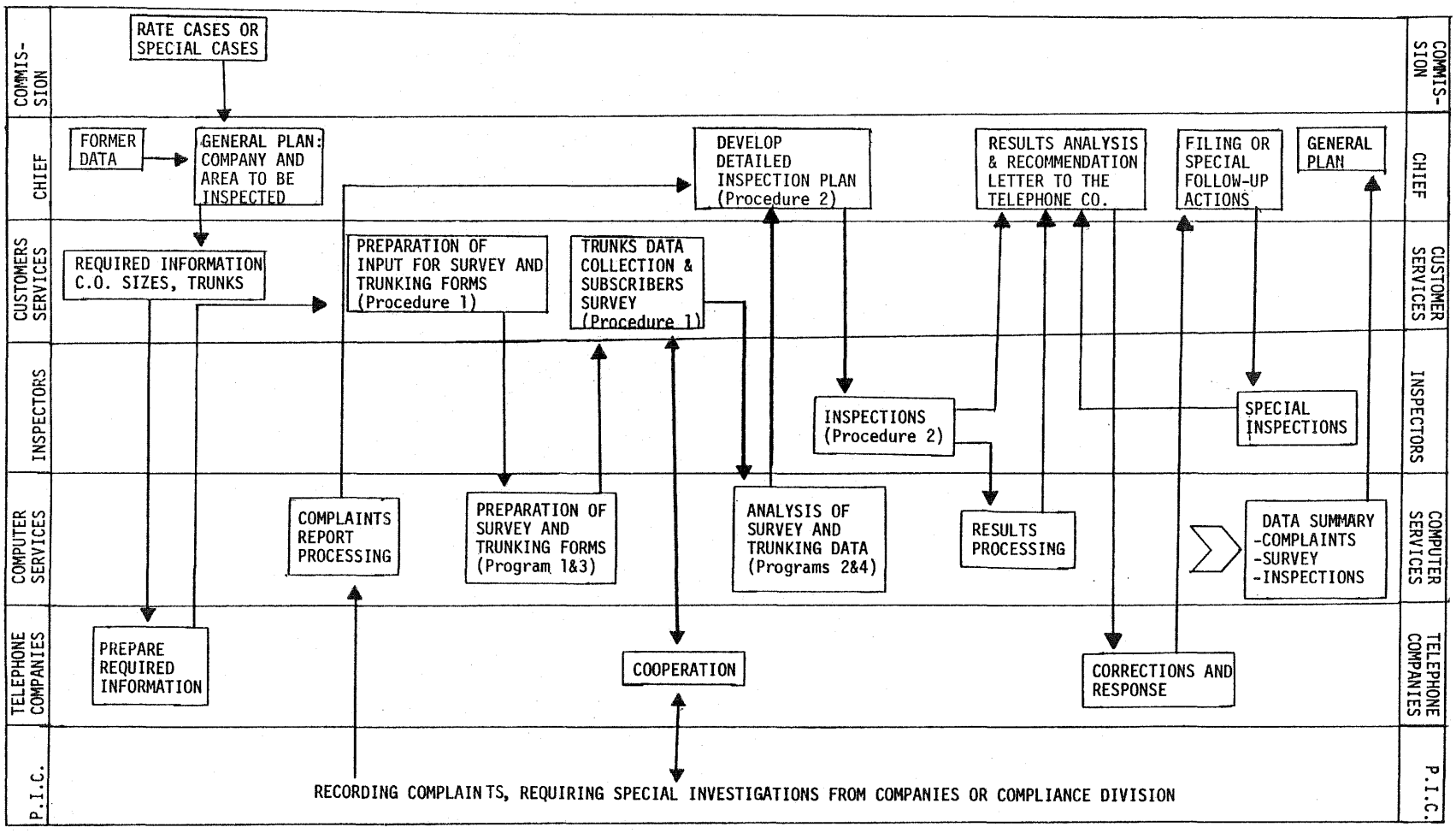
Information Flow

The chart below shows the sequence and directions of the flow of information for the processing of quality of service assessments. The head and tail of each arrow is marked with an action which either initiates an information flow or is precipitated by the flow of information. The horizontal bars block off the organizational units receiving or generating the information flows. The listing of the organizational units does not imply any hierachical order but was sequenced so as to shorten the arrows and simplify the diagram. Note the mention of the two procedures manuals and program specifications. This is to indicate which actions require the use of these documents or the materials prescribed by them.

About the Minimum Standards

Each major paragraph of A.O. 227, usually defines a minimum standard that telephone companies must meet. If effort is expended by the P.U.C.O. in order to measure how well these standards are being met then such knowledge must in some way help satisfy the organizational objectives of the Compliance Division. Therefore, the Director of the Compliance Division was asked to rate each standard regarding its importance in accomplishing the four objectives stated earlier. The rating scale consisted of the numbers 1, 2, 3, and 4 to represent the ratings very important, important, not so important, and relatively unimportant respectively. The chart

ACTIONS AND INFORMATION FLOW CHART



below gives the resulting rating for each minimum standard and each objective. Also given is a brief statement of how or when each minimum standard is checked in the new procedure design with the reference document given in parentheses. Finally, for some standards a statement may be given about how the wording of that standard may be changed in order to facilitate the inspection or measurement process. Such changes may not necessarily improve the standard but will simply help overcome some practical difficulties the current wording creates.

Paragraph No. in A0227 4901:1-5-	Shortened description of minimum standard	Objective Rating				How or Where Checked	Recommended Change
		Rate	Regi-men	Public	227		
05-B	90% of new orders complete within 5 days	3	3	1	1	Record check at the business office or company furnished report (Procedure II)	
05-B	All new orders complete within 30 days except when special equipment is involved	4	2	2	2		
05-C	99% of all new orders complete within 90 days	2	1	1	1		
05-D through H	Service regrades order completion times, records and notification	3-4	2	3	2		
06	Complaints corrected within 10 days	2	1	1	2	Information from PIC; Customer Services action; Customer Surveys; Special Inspections; Reports from companies (Procedures I & II)	
09-B-1	Dial tone within 3 sec. 97% of the time	1	3	2	1	Analyzer tests at random offices (Procedure II)	Eliminate reference to busy hour and increase standard. See interim report on this subject in the appendix, also see example alternatives from other states in the appendix
09-B-2	Intraoffice calls successful 90% of time	1	3	2	1		
09-B-3	Interoffice and E.A.S. will not encounter an all trunks busy signal 95% of time	1	3	2	1	Trunk traffic data from company records and analyzer tests on selected trunks (Procedures I & II)	Same comment as above concerning busy hour but should state "will not encounter an all trunks busy or equipment malfunction condition."

Paragraph No. in A0227 4901:1-5-	Shortened description of minimum standard	Objective Rating				How or Where Checked	Recommended Change
		Rate	Regimen	Public	227		
09-B-3	Toll connecting or tributary toll trunks will not encounter an all trunks busy signal 97% of time	1	3	2	1	Trunk traffic data from company records (Procedure I)	Same comments as above and change to complete toll connections instead of only connecting and tributary links
10-A	Toll calls will be answered in an average of 10 sec.	1	3	2	1	Manual tests (Procedure II)	Eliminate the statement that the average answer times be during a consecutive thirty day period
10-B	Intercept or directory assistance answered in an average of 10 sec.	1	3	3	1		
10-C	Calls to repair service answered in an average of 10 sec.	1	2	1	1		
20-A and 29-C	Interruption in service cleared in 24 hours	1	2	1	1	Inspection of line cards in repair centers (Procedure II)	
22-B	Proper loop resistance	4	4	4	2	none	
22-C	Transmission loss on local calls less than 10 decibels	2	3	3	1	Subjective judgement of transmission quality during subscriber survey and manual test calls (Procedures I & II) Followup could include precise measurement	
22-D	Transmission loss on toll calls less than 5 decibels	2	3	3	1	None, unless during followup of subscriber complaint or subscriber survey	

Paragraph No. in A0227 4901:1-5-	Shortened description of minimum standard	Objective Rating				How or Where Checked	Recommended Change
		Rate	Regi-men	Public	227		
29-E	Less than 7.5 trouble report/ 100 lines per month	1	4	3	1	Inspector visits all maintenance center, may obtain company statistic or take a sample of line cards (Procedure II)	
27-B-1	Min. of 1.5 hour battery with automatically switched backup power	3	4	4	1	Every office entered for any reason is checked by the inspector for these standards (Procedure II)	
27-B-2	Min. of 3 hour battery with manually switched backup power	3	4	4	1		
27-B-3	Min. 4 hour battery without permanent backup	2	3	4	1		
04-B-2	Party line limitation	1	2	2	1	Determinable from line card information at maintenance centers (Procedure II)	
13-A	Directory assistance information supplied to the operator within two days of change	3	4	3	2	Special inspection only if problem appears important in surveys and/or P.I.C. complaints	
15-B	Signs in public pay stations replaced within 3 business days	3	3	3	2	None, unless several complaints	
23-E	Meter testing program	3	2	3	2	Asking questions of the personnel at maintenance centers will reveal the extent of their testing program (Procedure II)	

Implementation

Steps

The implementation of the two procedures manuals provided in this study may be accomplished in three phases. A special effort was made to maintain as much compatability between the current and new procedures as possible so that implementation would be eased and computer programs already in use would require little or no modification.

One may think of the current procedures as a set of technical activities all performed at or around a given central office with the objective of determining the quality of service being provided the subscriber of that office and identifying those incidences where minimum standards are not being met. The new procedures prescribe few major changes in the technical activities themselves but make changes in the following way:

1. Some activities are eliminated.
2. Some activities are shifted from the technical personnel to the newly created Customer Services personnel, hence the separation of procedures into two manuals.
3. The remaining activities are separated into different groups of activities:
   A. Test calls
   B. Visual inside plant inspections
   C. Outside plant inspections
   D. Those that may take advantage of centralized facilities in metropolitan areas.

Each group is accomplished at locations chosen especially for the group involved, thus they are not all done in each office selected. However, as the metropolitan area gets smaller, the new procedures will be more similar to the current ones until a single office metro area is reached, then the new procedures will be almost identical to the current procedures.

The first phase of implementation should concentrate on the training of the Customer Services personnel in their use of Procedure Manual I and simultaneously the development of the computer programs described in the Computer Program Specification document, that support the activities of these people. This training has already begun.

The second phase would implement Procedure Manual II as the opportunities arise from work completed in Phase one. This should require no special training

since the technical inspectors are already familiar with each technical activity, but careful planning is needed to efficiently orchestrate their movements about the metropolitan area.

The third phase is a followup where adjustments are made. There are several steps in the new procedures that specify fairly lengthy manual computations with numerical data. After some experience with these it may be found desireable to have computer programs developed to automate these steps.

As these three phases are carried out the new procedures will begin developing data that is somewhat different from previous data and thus new interpretations of the results will need to be developed by management. Below are the specific instances of new interpretations.

Interpreting the New Data

The Compliance Division already receives a computer summary of test call results. The new procedures do not recommend any change in the forms for recording the test call data so that these summaries may continue without program modification. However, interpretation of the data will be somewhat different. Intraoffice test call summaries will be identical to previous such results, but the E.A.S. and interoffice data summaries will average the results of test calls over the several worst trunk groups in each metropolitan area (as determined from company records). Thus, for intraoffice calls the overall completion percentage is a fair estimate of the kind of service the average subscriber would expect to receive but the interoffice and E.A.S. completion percentage is an estimate of the worst service an average subscriber would expect to receive and that the overall service is expected to be much better than that observed on the test calls. The trunk traffic data gathered in the new process provides supplemental data to get a better understanding of the overall adequacy of service over interoffice trunking.

For both dial tone response time and intraoffice test calls, the procedure manual specifies a method that will spread test calls to different test numbers over a two day period of testing and record the results each hour. The results are then summarized within each office in the following way:

a. % of attempts successful on all calls for both days.

b. % of attempts successful on all calls for each hour of each day.

c. % of attempts successful on all calls for each test number for all hours and both days.

d. The average over the two days of the lowest percentage of each day computed in b.

Once these percentages were computed it was suggested that they be compared with the minimum standards given in Table I

TABLE I: Suggested Minimum Standards for Test Percentages

	For dial tone tests	For intraoffice tests
a	99.9%	98-99%
b	97.0%	90%
c	99.9%	98-99%
d	97.0%	90%

Since all test calling programs are subject to random events every failing test result has an interpretation and an alternative explanation. In all cases the alternative explanation is that during the test period exceptionally high traffic loads were being offered to the equipment group being tested by these particular test calls for which the system failed to meet the standards given in Table I.

Table II lists several possible combinations of outcomes that do not satisfy standards given in Table I, it also gives the interpretation of each and indicates a level of confidence one should have verses the alternative explanation given above. The confidence indications are:

GC - greatest confidence

VC - very confident

C - confident

U - the interpretation is unlikely to be true. (but is possible)

It should be pointed out that the minimum standards listed by category d & b are precisely those stated in A.0.227 while the others are simply indicators.

TABLE II: Test Call Interpretations

Combination of failures	Interpretation	Confidence
d	The office is not in compliance with A.O. 227 para 09-B-1 or 09-B-2 depending on which test failed.	C
d and several valves in b.	Same as above.	VC
d, several valves in b, a, several valves in c,	Same as above	GC
a	Same as above	U
a, several valves in b	Same as above	C
a, several valves in b &, several valves in c	Same as above	C
any valve in C	The particular equipment groups used when the failing test number is called has some problem with it.	C

Notes: 1. The dial tone tests only test the equipment associated with the 16 lines that the analyzer is hooked to so that broad conclusions about office performance is dangerous. Nevertheless, when some equipment fails to provide adequate service, some subscribers fail to receive adequate service thus the A.O.227 standards are still applicable to these particular equipment groups.

2. All the confidence ratings improve when the margin of failure is large.

Metropolitan area inspections are intended primarily to assess quality of service in metro areas rather than offices. The assessment should not be a single conclusion that says the metro area is in compliance with A.O.227 but should be a group of multiple assessments each making a conclusion about a small group of minimum standards delineated in A.O.227 which have been checked with a specific set of inspection procedures. Furthermore, the assessment should estimate (when possible) the extent of noncompliance in the area if any is found. For example, suppose 10 offices out of a total population of 30 in a metropolitan area are selected randomly and given a visual inspection to determine if they have a satisfactory maintenance program. Further suppose that in the judgement of the inspector two offices are judged substandard. Then in addition to itemizing the difficulties

identified in those two offices it would be estimated that (2/10) * (100%.) or 20% of all offices in the area (20% * 30 or 6 offices) are substandard. Similarly, if the three worst trunks in the system are tested and only one found bad then one would estimate that only one trunk connection in the metro area is bad. However, if all three were bad and a second set of the three next worst were tested finding two bad, the estimate would be 5 bad trunks, all specifically identified.

For a final example suppose 10 of 30 randomly selected central offices were tested for call completion percentage and one failed, then passed after corrective action and a followup test. Also suppose a second metro area inspection occurred and 10 out of the remaining 20 offices were selected and tested yielding one failure. Then a reasonable assumption is that the first 10 offices tested (some time prior) are still good so that the estimate of number of offices not providing adequate service with respect to A.0.227 para 09-B-2 is (1/10) (20) = 2. If the first bad office had not tested good on the followup then the estimate is (1/10)(20) + 1 = 3. If there is reason to doubt the assumption stated above then 10 offices selected in the second sample should have been drawn from all 30 central offices and the new estimate stated independently of the first inspection results.

APPENDIX A- THE FIRST INTERIM REPORT

TO: Mr. Alan Pound

FROM: C. A. Mount-Campbell, Ph.D.

SUBJECT: Quality of Telephone Service Study Interim Report

DATE: June 28, 1978

The PUCO order 227, "Telephone Minimum Service Standards", sets out a number of specific requirements concerning the quality of telephone service. These requirements follow closely those specified in the NARUC Model Communications Service Rules (September 20, 1973). In regard to defining performance standards for a complex communication system these standards are well designed. When pertaining to the performance of the equipment and lines the criteria are stated in the same terms as engineering design criteria for such systems. The difficulty arises in trying to measure the performance of an operating system against some of these standards.

Discussions with PUCO Compliance personnel, GTE personnel, and the exercise of the nominal group technique with the six PUCO telephone inspectors have indicated that the percent of calls completed is among the most important guages of overall service. For some time now we have focused our attention on the call completion criteria, not only because of its importance, but also because of the time, method, and equipment currently being used in an attempt to test central offices for their performance as measured against these standards. We also considered this part of the quality assurance program design a particularily difficult one because of the cost involved in doing the testing correctly. The final recommendation may be that the PUCO criteria be modified to something that can be more easily tested even if it is a slightly less precise statement of system performance. Before making any recommendation some issues should be discussed.

Paragraph 4901:1-5-09 (of the 227 order) Adequacy of Service subparagraph (B) states;

> (B) Each telephone company shall provide switching equipment, trunking and associated facilities for the handling of local and toll traffic, designed and engineered on the basis of realistic forecasts of growth so as to meet or exceed the following service standards during the average busy season, busy hour:

(1) At least ninety-seven per cent of all calls will receive dial tone within three seconds in each exchange.

(2) At least ninety per cent of all local telephone calls within a central office will encounter a ring back tone, line busy signal or intercept facility after dialing the required number of digits. (See rule on intercept service.)

(3) For local exchange and extended area service, at least ninety-five per cent of all calls offered to any interoffice or extended area service trunk group within the local calling area will not encounter an all trunk busy condition. (For toll connecting or tributary toll trunks, this figure shall be at least ninety-seven per cent.)

Concentrating on paragraph (2) one sees that 90% of all calls offered to a central office destine for a connection within that office should, during the busiest hour of the average busy season, successfully negotiate all required interconnecting switching devices. In paragraph (3) one sees that if these calls are destine for a subscriber in another central office (same exchange area) or an extended area then the completion rate through the trunking should be 95%, also during the busiest hour of the average busy season. Actually the hour of the day can have no consistent impact upon the performance of a central office but the actual traffic being offered during that hour is of utmost importance. Analysis of traffic distribution patterns can identify the traffic levels offered to a central office, or telephone system, during the busiest hour of the average busy season. The analysis can also identify the hour during the day that will most likely experience that level of traffic. To summarize, "the busy hour of the average busy season" refers to a level of traffic more than it does a time of day, but it will identify a time of day during which that level of traffic is most likely to occur. The great majority of the time of the day not identified as the busy hour will experience lower levels of traffic than referred to by the PUCO standards. Only on rare occasions will the traffic be higher since the PUCO standard refers to an average of daily peaks.

With this knowledge one may analyze the current practice in testing the Adequacy of Service standards, but first let us discuss the potential causes of inadequate service:

a) INADEQUATE EQUIPMENT - Refers to an insufficient number of parallel paths for communication connection with respect to the traffic in the system. This problem will not manifest itself at low traffic levels.

b) INADEQUATE MAINTENANCE - A trunk, switch, or some other system component may become defective thereby reducing the number of good paths through the system for some (or all) subscribers. If not attended to immediately it could cause great degredation in service depending upon the location of the defective component in the system. The reason is that not only is the number of good paths reduced but it is also possible for a call to hit the defective component even when other good paths are available. The problem is aggrevated at high traffic levels because the chances of hitting the defective component are increased. It is not always possible to provide immediate repair of such components, but the service may be improved on an interim basis by "turning down" the defective component. This is a process which grounds the defective equipment thus essentially removing it from service. The number of paths through the system is still less than before but the service is improved by making it impossible for a subscriber's call to be blocked by this piece of defective equipment. If too much "turning down" is practiced before complete repair is affected then a problem will manifest itself as situation a) INADEQUATE EQUIPMENT.

c) IMPROPER LINE BALANCING - If the lines for the heaviest users of the system are all connected to the same linefinder then that portion of the system will experience the most traffic and thereby give the worst service. If these subscribers are connected to the system in a way to spread them out then their service will be improved without really reducing service to the other subscribers. This problem will manifest itself as situation a) INADEQUATE EQUIPMENT localized to certain areas in the system (probably linefinders).

All of these problems can be identified by extensive traffic studies. At one time the PUCO inspectors performed traffic studies at great expense of time and money. It was rightly argued that doing these studies was the responsibility of the telephone companies and not the PUCO.

Currently the PUCO inspectors use a Model TTS 41-3 Central Office Service Analyzer to test the performance of central offices. The analyzer is connected to up to 16 linefinders at once just as 16 new scribers would be.

It will then automatically place calls through the system to any pre-programmed number. Test numbers are used to prevent an undesirable disturbance of actual subscribers. The progress of each call through the system is monitored by the analyzer which will detect several different kinds of failures. Thus the analyzer provides an efficient means of gathering the data concerning percent of calls completed and could also provide some data concerning excessive transmission loss or gain.

The PUCO inspectors currently employ the analyzer to determine dial tone response time and percentage of calls completed in an attempt to measure central office performance against PUCO Order 227, paragraph 4901:1-5-09. Unfortunately, no attempt is made to coordinate this test calling with the busy hour. There are sufficiently many test calls made over a long enough period of time that the busy hour is usually included in the test, but that busy hour data is not separated from the majority of data which is collected from less than busy hours. This is equivalent to running an experiment and not controlling a factor which influences the outcome of the experiment. In this case the uncontrolled factor (traffic) always influences the test in the same direction thus creating a bias. This bias favors the telephone company. Clearly one cannot control the traffic in a system, but scheduling the test calls to be made only during the busy hour will tend to minimize the bias. Testing during several different day's busy hours will tend to eliminate the bias.

This concern for the impact of traffic would not be so great if it was not such a substantial impact. Each curve in Figure 1 shows the percent of completed calls that would be observed by the PUCO team as a function of the percent of busy hour traffic actually being offered to the system during the testing period. The one on the left shows the result for a central office that barely passes the 90% completion criteria. The one on the right shows the result for an inter office connection that barely passes the 95% completion criteria. One can see from these curves that, except when faulty equipment has not been "turned down", the observed percent completion is well over 99% when traffic is 80% of the busy hour traffic. When the traffic is 90% of busy hour traffic, the observed completion percentages will be 95% and 98.5% respectively. When the actual traffic is not taken into account (as it isn't) these percentages look good against the PUCO standards when in fact the office is marginal.

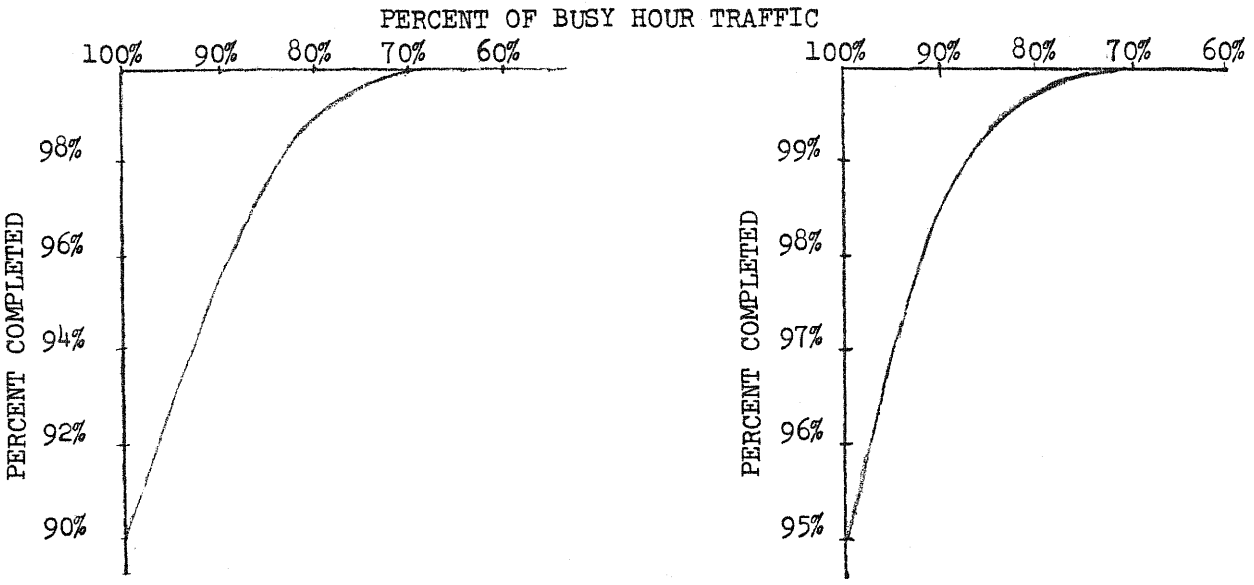


Figure 1, Impact of Traffic on Performance

In another example we use actual traffic data from a Bell trunk group and estimate what would be observed by the PUCO inspectors if the analyzer is used from 9:00 a.m. to 12:00 noon and from 2:00 p.m. to 5:00 p.m., Monday through Friday. We also assume the trunk group is marginal for its average busy season, busy hour traffic level estimated from the following data to be 704.5 ccs:

TABLE I: Traffic Study Data

TIME	MON	TUE	WED	THU	FRI
0900	0 00593	0 00637	0 00486	0 00466	0 00480
1000	0 00576	0 00526	0 00540	0 00386	0 00456
1100	0 00530	0 00502	0 00578	0 00558	0 00656
1200					
1300					
1400	0 00576	0 00492	0 00526	0 00515	0 00538
1500	0 00582	0 00490	0 00478	0 00616	0 00616
1600	0 00648	0 00508	0 00488	0 00546	0 00638
1700					
1800					
1900	0 00554	0 00542		0 00622	0 00522
2000	0 00756	0 00532		0 00658	0 00432
2100	0 00570	0 00744		0 00662	0 00376

Finally we assume an equal number of sample calls are made during each hour of the test period. Based on Figure 1 and Table I a good estimate of the percent of test calls completed is 99% for a trunk group that just passes the minimum standard of 95% during the busy hour. If we further assume the office is not marginal, but in fact fails to satisfy the minimum standard by completing only 89% during the busy hour traffic, the inspector's test calls would still produce a 97% completion rate.

To summarize these findings it can be said that the PUCO inspector would expect to see, during their testing procedures, a percentage of completion that is much better than would actually be provided during the average busy hour. Therefore, if, for example, 100 or even 1000 or 1,000,000 calls were made over a trunk group and 97.5% of these calls are completed then it is not possible to make any definitive statement relative to the PUCO order, i.e. one could not say the trunks comply with minimum standards nor could one say that they do not comply with minimum standards. On the other hand if completion percent is 94% then one could say with very good confidence that the trunk does not comply with minimum standards, but such an outcome is highly unlikely unless a critical piece of equipment is defective and has not been "turned down" or the trunk group is grossly undersized for even less than busy hour traffic.

There are basically three alternatives available for resolution of these practical difficulties encountered when testing against the PUCO order. They are listed briefly and then discussed in the succeeding paragraphs:

1. Change the PUCO Order 227 paragraph 4901:1-5-09 as follows:

    a. Change from 90%, average busy season, busy hour to 97%, average for any typical business day during the busy season.

    b. Change from 95%, average busy season, busy hour to 98.5% average for any typical business day during the busy season.

    c. Change from 97%, average busy season, busy hour to 99.5% average for any typical business day during the busy season.

2. Do not change the PUCO order, but whenever the Compliance Division personnel find completion percentages less than the 97%, 98.5%, 99.5% stated above, a traffic study should be requested from the company involved in order to ascertain whether the minimum standards are being met.

3. Do not change the PUCO order, but reduce or eliminate the use of test calls in determining completion percentages. If other inspection procedures, customer complaints, or the customer survey indicate some possible problem with the service, then a traffic study could be requested from the company involved in order to ascertain whether the minimum standards are being met.

In Item 1 percentages of 97%, 98.5%, 99.5% were suggested for purposes of example. The actual values used would be up to the Commissioners. Presumably the ideal values would be those that are roughly equivalent to the busy hour criteria. However, if two offices, trunk groups, or tributaries have significantly different traffic patterns relative to their busy hour traffic, then the percentages that are roughly equivalent to the current criteria for the busy hour would be different so that a single set of values may not apply well in all cases. An alternative approach would be to disregard the current standards and establish the percentages that provide a judgemental answer to the question, "What service should any subscriber expect to receive on any call placed any time during a normal business day at the current prices?" Variances to such an order could be granted on a case by case basis for those offices with such unusual traffic patterns that satisfying the new standard would cause an extensive cost increase.

In Item 2, again the 97%, 98.5%, and 99.5% values were used for purposes of example. In this case the correct values to use are those that are roughly equivalent to the busy hour standards. We are currently using Bell traffic data to determine the extent of the difficulty caused by a disparity of traffic patterns as mentioned earlier.

If the appropriate percentages are determined in either item 1 or 2, then the test calling process would still require modification. The current practice (due to analyzer design) is to set in a test number and allow the analyzer to automatically cycle through 50 to 100 calls. This entire process takes less than one hour for any particular test number and would not be appropriate for determining the daily average percent of completions to the test number. To do it correctly will require the 50 to 100 test calls to be spread out randomly over the whole business day. In order to make efficient use of inspector time several test numbers (testing different equipment) would be tested at once by randomly selecting a test number from the list for each test call. This will require manual operation of the analyzer and manual recording of the results since the analyzer is not designed to operate automatically in this manner. Therefore, while the changes recommended in 1 and 2 would make it possible to make some determination concerning compliance without requiring that the inspectors do traffic studies themselves, the correct use of the analyzer will still require a great deal of inspector time and effort and take longer than the current procedures.

In item 3 test calling is deemphasized to a minor role in the inspection process. The main reason is that its benefit to cost comparison does not appear to be very favorable since the actual benefits do not live up to the anticipated benefits. The anticipated benefits that we have been able to identify are listed as follows:

1. Provide a means of determining the percent of calls completed as a test against the "Adequacy of Service" standards in the PUCO administrative order.

2. Identification and isolation of certain types of malfunctioning equipment which have not been turned down.

3. Helps the inspectors form an opinion about the overall condition of an office.

Benefit 1 is not actually realized because of the unreliability of the test results as shown earlier in this report. (Improvement in reliability comes at higher cost as discussed earlier.)

Benefit 2 probably results in the repair of some defective equipment at an earlier time than might otherwise occur although there is very little evidence of this happening frequently in the inspection reports on file at the PUCO headquarters. We estimate that at best a few hundred repairs a year are initiated in this manner by the PUCO inspectors. When compared to the several hundred thousand repairs that must occur in the over 1000 central offices in the state, the value of this trouble shooting appears very marginal. Furthermore, the activity of identifying isolated incidences of equipment malfunction does not provide the kind of information that would support a conclusion about the degree of compliance with the PUCO order.

Each inspection report contains a statement of opinion by the inspection team that a central office is in compliance with PUCO order 227 except as noted (if any). The noted exceptions occasionally point to the results of test calls. We have had inspectors tell us that the analyzer test calls tend to bear out the opinions they have already formed. In this sense the test calls help by providing one more bit of information in order to increase the confidence in the conclusions being made.

The cost associated with using the analyzer are dependent upon the size of office and community where the office is located. The identifiable costs are listed for the process for a typical office in a large metropolitan area: (the capital costs of the analyzer are not considered)

1. Administrative - The telephone company assigns 16 lines and numbers as if 16 new subscribers were being added to their central office. (Unfortunately, all test calls must be made through these same 16 lines.)

2. Set-up Labor

    a. Telephone company hooks up 16 lines.
    b. PUCO inspector waits for hook up.
    c. Telephone company unhooks 16 lines.

3. Operating Labor

    a. PUCO inspector operates and monitors analyzer.
    b. Second PUCO inspector may have some slack time while waiting for the analyzer to be completed.

Naturally all of these costs vary from time to time, place to place, and situation to situation. The worst situation is probably the large central office in a large metropolitan area since such an area will have more trunking to be tested. This situation will increase 3a and 3b. Cost 2b could result in anywhere from 30 minimum to a day depending upon the availability of persons to hook up the lines and depending on whether waiting time is actually lost. In the case of the inspection that we observed in Columbus, the major costs of analyzer test calls in terms of inspector time were as follows:

1. Delay time of one day for hook-up.

2. About 3 and one-half days inspector time for operating the equipment, including a fraction of a day planning where calls were to be made. This did not include the manual test calls.

3. The second inspector "stretched out" his activities so as to not finish before the analyzer tests were finished. (This is certainly a reasonable thing for him to do under the circumstances.)

Large metro offices such as this one represent the worst case situation due to the large amounts of inter office trunking. In this case 4.27 times as many test calls were made than are averaged per office at the more rural and smaller metropolitan area offices. The visual parts of the inspection are not so greatly affected by size. The entire inspection required a 9 man day effort (10 man days counting the loss of Friday afternoon). At this time a very subjective estimate is that a 7 man day effort would have resulted from a carefully designed random sampling plan. A much more precise estimate of 4 man days would have resulted if the analyzer test calls had not been made at all.

The crucial question thus becomes, "Are the benefits worth the costs?" Our answer is no for large metropolitan areas where traffic data is usually available and yes in rural offices where it is less costly to use the analyzer and where the traffic data is not so readily available.

It is for the many reasons stated in this report that we recommend alternative 3 which reduces the importance of test calling as a matter of routine but whose role may be adjusted to best match the situation in the rural offices. In those situations where a small community is involved without readily available traffic data the strategy recommended is alternative 2 is perferred.

APPENDIX B - EXAMPLES OF OTHER MINIMUM STANDARDS

Examples of Other Minimum Standards

Below are excerpts from the standards of New York and California concerning adequacy of service.

California

The following pertains to dial tone responses with no references to busy hour:

"Standard Service Range at or above 97.7% within 3 seconds."

The following pertains to percent of calls not encountering all trunks busy or equipment malfunction and no distinction between interoffice or intraoffice calls:

"Standard Service Range at or above 98.0%"

Again, there was no reference to the busy hour.

New York

In the following one may note that two standards are given, design standards and performance standards. Also note that busy hour, or recurring busy hour, are variously used or not used. In its place, a time period requirement is used which would create even more difficulties in a testing program than the busy hour does.

"DIAL SWITCHING DESIGN STANDARDS. (a) Each utility shall employ a design criterion for dial tone delay for the average busy hour of the busy days of the busy season of either:

(1) 1.5% of attempts may fail to receive dial tone within 3 seconds or

(2) 2% of attempts may fail to receive dial tone within the normal connection time of the serving equipment.

(b) Each utility shall employ a design criterion of 4% or less overflow or all trunk busy conditions for overall intraoffice switching during the average busy hour of the busy days of the busy season.

(c) Each utility shall employ a design criterion of 2% or less overflow or all turnk busy conditions on each final trunk group of a local network during the average busy hour of the busy days of the busy season.

(d) Each utility shall employ a design criterion of 2% or less overflow or all trunk busy conditions on each final trunk of its intertoll network during the average busy hour of the busy days of the busy season.

(e) Each utility shall employ a design criterion of 2% or less overflow or all trunk busy conditions for each of its toll connecting, toll completing or toll switching groups (operator office, recording completing, SATT, CAMA, etc.) during the average busy hour of the busy days of the busy season."

"603.16 SUBSTANDARD SWITCHING SERVICE. (a) At locations equipped with dial tone speed measuring devices, dial tone service shall be deemed substandard if more than 2.6% of attempts during the recurring busy hour of the business days of a month fail to receive dial tone within 3 seconds in any originating entity for three consecutive months.

(b) At dial service observed originating entities, service shall be deemed substandard if 3% of measured local attempts at an entity encounter an all trunks busy, overflow condition or equipment irregularity for each month of a three-month period.

(c) At DDD service measured locations, service shall be deemed substandard if 5% of measured DDD attempts per report echelon encounter an all trunks busy, overflow condition or equipment irregularity for each month of a three-month period.

603.17 SUBSTANDARD MAINTENANCE SERVICE. (a) Maintenance service shall be deemed substandard if the rate of customer trouble reports for a reporting unit exceeds 6.1 per 100 stations or report units for each month of a three-month period."

APPENDIX C - THE SECOND INTERIM REPORT

3 August 1978

TO: Alan Pound

FROM: C. A. Mount-Campbell, PhD
David Slyper

SUBJECT: Interim Report 2

This report is divided into four sections. The first section describes the results of the pilot survey of the subscribers connected to the U. Arlington office. Section two identifies and discusses several alternatives concerning the PUCO surveys in general while section three recommends one of these alternatives for the short run and a second for the long run. Section four is a draft for a procedures manual for different ways of generating telephone numbers for random calling.

SECTION I: The Telephone Survey

A survey was conducted to get the subscribers' view of the service provided by the telephone company in general, and their central office in particular.

A structured questionnaire was designed and tested. The questionnaire included four parts:

(a) Identification of the subscribers line and time of interview.
(b) Difficulties mentioned by the subscriber.
(c) Subscribers opinion of the service.
(d) Strata identification.

A list of classified difficulties, based on the complaints filed by P.I.C. and on the PUCO criteria, is included in the questionnaire. The list is divided into classes of technical difficulties and classes of administrative difficulties. A sample of the survey instrument used is on the following pages.

Two random samples of 200 telephone numbers each were generated using the methodology given in section four. Both samples were selected

TELEPHONE PERFORMANCE QUESTIONAIRE

Introduction: HELLO, I'M CALLING FOR THE PUBLIC UTILITIES COMMISSION. WE'RE CONDUCTING AN INSPECTION OF LOCAL TELEPHONE FACILITIES. OUR INVESTIGATION INCLUDES A CUSTOMER SURVEY, AND AS PART OF THIS WE NEED SOME INFORMATION FROM YOU.

THE FIRST QUESTION INVOLVE THE OPERATION OF YOUR TELEPHONE.

Interviewer: _____

|_|_|_|_|_|_|_|_|_|_| Date |_|_|_|_|_| Hour |_|_|_|_|

1 10 11 15 16 19

Question 1:

THIS PAST WEEK, HAVE YOU HAD PROBLEMS IN PLACING OR RECEIVING TELEPHONE CALLS? (Do not suggest an answer. Classify the customer's response according to the following categories. You may fill more than one. If asked, give examples only of the top 3 categories.)

Cut off in the middle of a conversation	20
Late dial tone	21
Slow connections	22
Busy trunks (Fast signal)	23
Noise on the line	24
Cross talk	25
Equipment	26
Line (Dead)	27
Intercept	28
Wrong number	29
Doesn't get all incoming calls	30
Party line Equipment	31
Other	32

Question 2:

HAVE YOU HAD ANY PROBLEMS WITH THE TELEPHONE COMPANY OR ITS SERVICES?

(Instructions are the same as Question 1.)

Directories	33
Directory assistance	34
Repair service	35
Non payment disconnection	36
Billing	37
Regrades	38
New installation	39
Other (Remarks)	40

Comments: _____

_____

Question 3:

CONSIDERING ALL THIS, WOULD YOU RATE YOUR TELEPHONE AS:

VERY GOOD	1
GOOD	2
FAIR	3
POOR	4

41

Comments: _____

_____

Question 4:

RESIDENT	0
OFFICE	1

42

Question 5:

AS A LAST BIT OF INFORMATION THAT WE NEED TO KNOW, PLEASE ESTIMATE THE NUMBER OF LOCAL CALLS YOU MAKE IN A USUAL WEEKDAY:

LESS THAN 3	1
3-5	2
5-10	3
10-15	4
MORE THAN 15	5

Comments:

43

Question 6:

For Office Numbers:

ESTIMATE THE NUMBER OF LONG DISTANCE CALLS YOU MAKE IN A USUAL WEEKDAY:

LESS THAN 5	1
5-10	2
11-15	3
16-20	4
MORE THAN 20	5

Comments:

44

For Resident Numbers:

ESTIMATE THE NUMBER OF LONG DISTANCE CALLS YOU MAKE IN A USUAL WEEK:

LESS THAN 2	1
2-5	2
MORE THAN 5	3

Comments:

45

IS THERE ANYTHING ELSE YOU WOULD LIKE TO ADD FOR OUR INFORMATION ?

randomly from the 486 and 488 prefixes in Columbus (U. Arlington Office). One group was contacted before the PUCO inspection of that office and the other group was contacted after the inspection. Using PIC personnel dictated the hours of interviewing to be the usual working hours, a fact that might have an effect on the representativesness of the results.

The survey's statistics indicate 95% response rate among those persons answering their phones. Thirty percent of all calls attempted yielded a completed interview, with 26% completed in the first attempt and an additional 4% in the second attempt to contact those not answering the telephone on the first attempt.

A time study of the interviewers was conducted, giving the following results which may be used to estimate overall cost of various sample sizes:

(a) A successful attempt (including dialing, waiting, interviewing and filling out the instrument) generally takes between 1.83 min. to 5 min. with an average of 2.35 min.

(b) An unsuccessful attempt generally takes between .67 min. and 1.07 min. with an average of .92 min.

The following list summarizes the subscriber responses based on 160 completed questionnaires:

Question 1: (Technical Troubles)	SURVEY RESPONSES IN % OF SUBSCRIBERS
Cut off in the middle of a conversation	0
Late dial tone	2.5
Slow connections	1.9
Busy trunks (Fast signal)	5.0
Noise on the line	5.0
Cross talk	2.5
Equipment	0
Line (Dead)	0.6
Intercept	0
Wrong number	2.5

	SURVEY RESPONSES IN % OF SUBSCRIBERS
Question 1: (Technical Troubles) (cont.)	
Doesn't get all incoming calls	5.6
Party Line Equipment	0
Other	6.9
Question 2: (Administrative Troubles)	
Directories	0
Directory Assistance	0
Repair Service	1.3
Non Payment Disconnection	0
Billing	3.8
Regrades	0
New Installation	0.6
Other	1.9
TOTAL	8.4
Question 3: (Service Rating)	
Very Good	50.6
Good	45.6
Fair	2.5
Poor	1.3
Question 4 (classification)	
Resident	75.0
Business	25.0
Question 5: (Usage)	
Less than 3 Local Calls/Day	30.6
3-5 Local Calls/Day	27.5
6-10 Local Calls/Day	17.5
11-15 Local Calls/Day	7.5
More than 15 Local Calls/Day	16.9
Question 6 (Usage)	
Offices Toll Calls Per Business Day	
1 Less than 5	62.5
2 6-10	9.3
3 11-15	3.1
4 16-20	6.2
5 More than 20	15.3

Question 6 (Usage) (cont.)	SURVEY RESPONSES IN % OF SUBSCRIBERS
Residents Toll Calls Per Week	
1. Less than 2	90.4
2. 2-5	15.9
3. Less than 5	3.7

Twenty four percent of the interviewees had at least one type of difficulty in the operation of their telephone equipment, while 6.5% had had two or more types of difficulties. Only 7.3% said they had had any difficulties with the telephone company's administrative services. A total of 29% mentioned at least one difficulty of either type during the week prior to their being interviewed. There did not appear to be any relationship between the number of difficulties a subscriber mentioned and his level of usage or the strata (business or residence) to which be belongs. Based on this sample one cannot conclude that the subscriber's opinion of the service is being affected by the number or type of difficulties he/she has had, or the level of usage. However, his/her opinion is affected by whether or not he/she has had difficulty.

During the inspection of this CO the PUCO inspectors also conducted their normal survey of 25 subscribers selected randomly. Their style and format of questioning is the result of what each inspector has developed on his own, thus it has not been standardized. In this survey no subscriber graded the service less than good. The probability that the difference between the grading results of the PIC survey and the inspectors survey would be explained completely by chance is 33%, which does not show significant difference between the two surveys. However, in the inspectors' survey only one difficulty was mentioned (4%) when the PIC survey found that 29% of the subscribers metnioned at least one difficulty. The probability that this difference can be explained completely by chance is only 0.1%. Therefore one must conclude that the standardized survey instrument and technique are more effective in this instance in indentifying problems that subscribers feel they were having than was the inspectors' technique.

SECTION II: Alternatives

In this section we present and discuss some alternatives concerning the suscriber survey. These alternatives are listed below and followed by a discussion of each. The next section will recommend one of these alternatives and offer justification of the recommendation. The major alternatives that we have been able to identify are:

1. Conduct telephone surveys of randomly selected subscribers in such a way as to draw inferences about exchange areas.
2. Conduct telephone surveys of randomly selected subscribers in such a way as to draw inferences about central offices.
3. Do not do any subscriber surveys.
4. Do subscriber surveys by mail.

The major differences between alternatives one and two are the sample sizes required to implement on a state wide basis and the uses to which the data may be put. For the multi-central office exchange areas, the sampling plan that would be designed for alternative one would make it possible to estimate proportions of subscribers in the exchange area who have had difficulties or who rate their service good, fair, or poor. Confidence intervals could also be placed on these estimates of proportions in order to more precisely represent the data. For purposes of rate cases, such estimates of proportions made by the independent state agency may be valuable input when:

a) interpreted in light of comparison with similar surveys in other exchange areas.
b) used to refute or support the results of surveys conducted by consumer groups.
c) used to refute or support surveys conducted by the telephone companies.
d) used to help determine the extent to which complaints received by the PIC reflect the attitudes of the population.

If any patterns of subscriber problems appear prevalent according to central office or according to type of problem then the PUCO could respond to this apparent public need by initiating a special inspection or by being particularly cognazant of the prevalent problem type during a normal inspection. This use of the data generated if alternative one is accepted is secondary in nature and opportunistic in the sense that it is done if and when such patterns develop. The sampling procedures and sizes would not be sufficient to insure measurement and identification of patterns that may exist among central offices.

Alternative two will require roughly the same sample size for each central office subscriber survey as alternative one would require for an entire exchange area. Furthermore, the total sample stratified on central offices may be used to make estimates of proportions in the exchange area, thus providing some data for rate case. However, one could not establish the confidence intervals as could be done in alternative one unless every central office in the area is surveyed. The main benefit of the larger sample sizes for each office for which a sample is taken is that stronger inferences could be made about each central office. Such inferences could be used to screen central offices to determine which should receive closer scrutiny or to supplement information obtained in a normal inspection.

Alternative three is clearly a viable one requiring full consideration. The reason is that any surveying method is expensive (see estimates in first section) and there is no minimum standard in A.O. 227 that refers to survey results.

Alternative four is probably the least expensive if a PUCO questionnaire is included by the phone company in the envelopes of a monthly billing and returned with the payments to the companies who would collect and deliver them to the PUCO. Printing and data processing costs would

be the only operating expense incurred by the PUCO, but initial implementation would require close cooperation with the companies, extensive pretesting of the questionnaire, and design of an automated analysis and information processing system. However, substantial data would be available for rate cases and allocating inspector effort in response to a public need. In fact all Compliance Division organizational objectives would probably be met best by the data gathered in this manner.

Before making a recommendation it is necessary to discuss sample sizes where a random sample is taken from a population with replacement (see the next section). If taken without replacement from a large population (i.e. a typical central office subscriber list for Columbus is a large population) the following sample size discussion also applies. If taken without replacement from a small population (less than 100 for example) then the required sample sizes would be somewhat smaller than given below.

The purpose of a sample is to make an estimate of the proportion of people who would say, for example, that their telephone service is good, or who would say that they had had problems with the telephone system. Unless the entire population is interviewed the estimate of these proportions is likely to be inaccurate. The amount of inaccuracy depends upon what the proportion actually is and upon the size of the sample. The most common way to represent the degree of inaccuracy in an estimate is to state it in terms of a confidence interval instead of a point estimate. For an example of this, suppose out of 400 subscriber contacted, 100 said that they had experienced trouble using their telephone, then a point estimate is p=100/400= 1/4= 25%. Thus we would estimate that 25% of the subscribers have had difficulty (in their eyes) with their telephones. The equivalent confidence interval statement would be: "The 95% confidence interval is [20.7% to 29.3%]". This statement is universally accepted to mean that there is a 95%

probability that the interval will contain the true proportion. Another way to state the above interval is 25% $\pm$ 4.3% or in general it may be thought of as ESTIMATE $\pm$ ERROR. We let E represent error in Figures one and two. The purpose of these figures is to show the relationship between the error (E) and the sample size (n) for various proportions (p) that we are trying to estimate by taking the survey. Figure 1 shows curves for 95% confidence while Fig. 2 shows curves for 90% confidence. To determine sample size a manager would first decide upon the confidence desired, then subjectively estimate the largest value for p (proportion) he would expect to see in a survey and finally decide upon the largest acceptable value for E. None of these subjective decisions need to be especially precise. For example, suppose the manager would like 95% confidence, expects to see p's no larger than the 30% to 40% range and would like E to be less than 6% or 7%. From Fig. 1, one locates 6% on the E scale (vertical scale) and reads across until curve p=.40 is encountered then down to the n scale to see that a sample size in the neighborhood of 250 subscriber contacts will give at least the desired results. Of course, if p is 3% to 4% instead of 30% to 40% an E of 6% is probably unacceptable. However, again from Fig. 1, a sample size of 250 produces an E of only about 2.5% to 2.6% when p is .03 to .04. That E may still be acceptable. If not, more data could be collected to improve E.

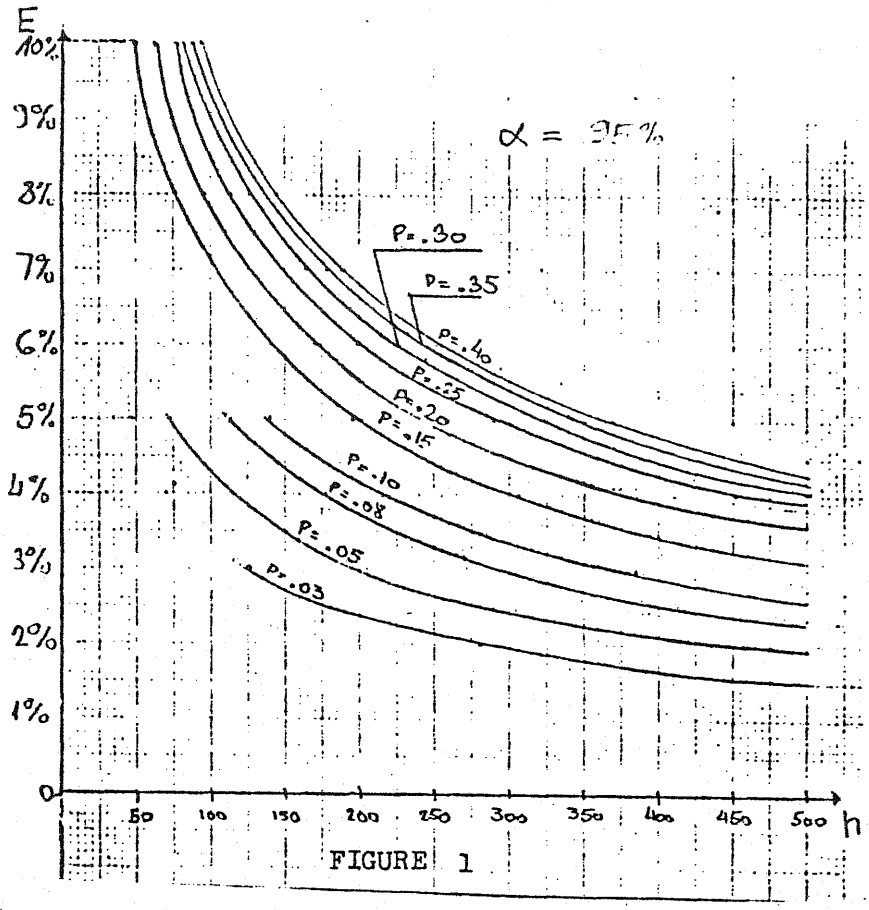


FIGURE 1

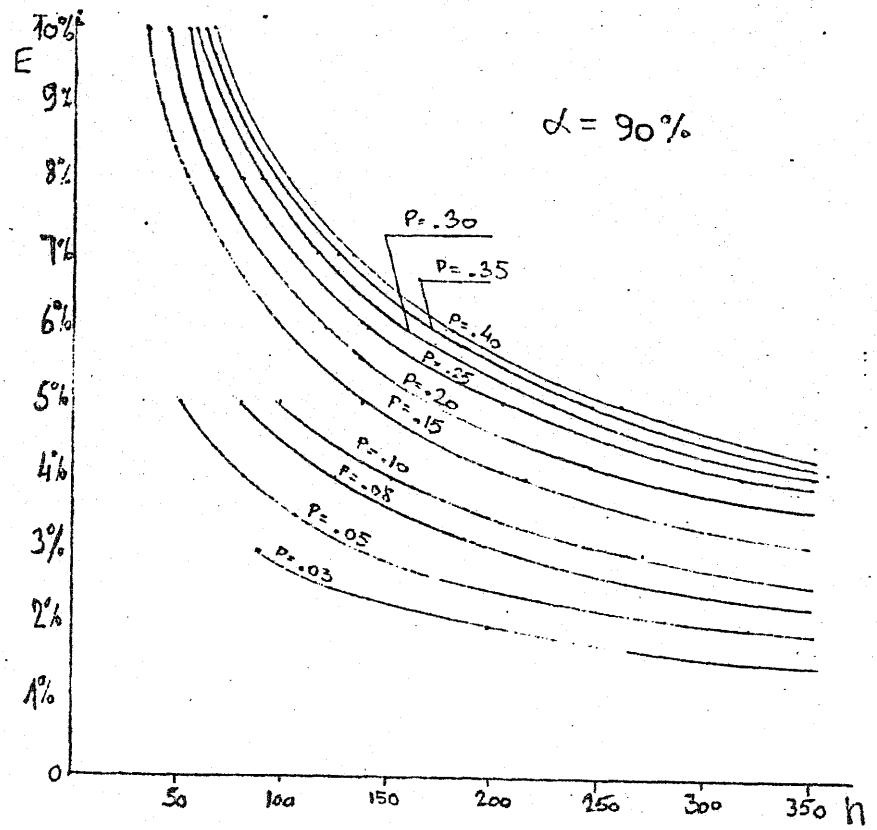


FIGURE 2

SECTION III: Recommendations

We recommend the short run adoption of alternative 1 for the following reasons:

1. Based upon a 90% confidence interval with E ranging from 2% to 6% as p ranges from 3% to 40% a sample size of 200 would be sufficient to make reasonably accurate statements about public opinion of service in an exchange area for purposes of rate case information, the division's most important objective. Alternative 2 would require about the same sample size for the survey taken in each central office inspected and would collectively provide a much less precise statement about opinion of exchange area service unless all CO's are surveyed. Furthermore, solicited public option about service in a central office cannot serve to accept or reject any part of an office with respect to A.O. 227. Thus, alternative 2 is more expensive than alternative 1 and degrades the information for rate cases while improving the unnecessary information about central offices.
2. A statistical contingency table could be used to analyze survey results from alternative 1 in order to screen central offices for special inspections. This will help accomplish the objective of being responsive to public need.
3. While alternative 3 is clearly the least cost it also does not help accomplish any objectives. It would seem likely that telephone companies and consumer groups may present their own survey or statements about public opinion of service in rate cases and therefore, an independent PUCO survey would also seem appropriate. Furthermore, by conducting surveys, the PUCO demonstrates to the telephone companies a strong interest in public opinion. This will help accomplish the objective of encouraging regimen for the system.

We further recommend that the standardized data collection instrument presented in the first section of this report be adopted for all surveys and that the task of administering these questionnaires be removed from the PUCO inspectors. The reason for this second recommendation is that the experience and skill of the PUCO inspectors is far greater than required to administer the survey. Furthermore, experienced telephone inspectors tend to interpret and record subscriber comments differently according to their experience and what they are finding in their inspections. Subscriber comments should be recorded as accurately as possible with as little interpretation as possible. This way the results of all surveys can be interpreted by one person.

As a long term goal we recommend adoption of alternative 4. The reason it could not be immediately adopted is the significant coordination, planning, testing, and system development work.

SECTION IV: Selection of Random Phone Numbers

Only persons listed in a telephone directory should be contacted for survey purposes. The procedures outlined below may be used to randomly select telephone numbers from a directory. When several phone numbers are selected randomly the entire set of such numbers is known as a random sample. The random sample is drawn from what is called the population which in this case is the list of all subscribers with telephone numbers in the directory. The main reason for taking a random sample is to infer something about the entire population. For example, if 10% of the persons contacted in the random sample said they had some difficulty with their telephone service in the last week then one would infer (or estimate) that 10% of the population would have said the same thing if they had all been contacted. In order to make such inferences with some degree of statistical confidence it is necessary that the random selection process follow a rule. The rule is that when a selection is being made, every telephone number in the population must have exactly the same probability of being the one that gets selected.

In all likelihood any individual could thumb through a directory and more or less "haphazardly" select telephone numbers that make up a good random sample (i.e. they follow the rule sufficiently well to make the inferences as described above). However, there is no guarantee that the "haphazard" process is unbiased (follows the rule) and is therefore indefensible from objection. It is for this reason that the following systematic procedures have been developed.

Selection With Replacement

Selection with replacement means that once an individual number is selected it is placed back into the population and may be selected again. There are certain situations where this is desirable. The

chance that one or more numbers will be selected two or more times is small for large populations and small samples, but will happen with increasing frequency with smaller populations.

Procedures for sampling with replacement:

STEP 1: Determine the first and last page number of which a telephone number appears and record them at the top of your paper.

a) If the last page number is less than 100 use random number table I.

b) If the last page number is less than 250 use random number table II.

c) If the last page number is less than 500 use random number table III.

d) For all others use random number table IV.

STEP 2: Arbitrarily select a row of the table to start and then proceed in a sequence across and down as in reading.

STEP 3: If the page number in column one is outside the range of page numbers at the top of the paper, skip to the second page number column. If that is also outside the range, skip to the next page number column, and so on, until one is found in the appropriate range. Turn to that page.

STEP 4: Next to the page number is a column number. Count from left to right in the directory the number of columns indicated even if you must turn a page to do so. Always let the left most column on the appropriate page be column number one.

STEP 5: Line up the ruler so the 0 marker lines up with the first telephone number in the column that has thus far been selected. Use the number from the table in the "scale" column next to your page and column number to locate a corresponding mark on the ruler.

STEP 6: Choose the first telephone number next to or below the mark just located on the ruler that has the desired prefix number for the survey. Record that number on your paper to make the call immediately. In either case place a small mark next to the number in the directory. If you have already marked the number because it had been selected in a previous step then go to step 8.

STEP 7: Select the next page number in the table and go to step 3.

STEP 8: If a number is selected more than once call that number only once but record the results of that call as many times as the number gets selected just as if those calls had actually been made again.

STEP 9: Go to step 7.

COMMENT: If the scale is too long for a telephone book and the scale numbers place beyond the bottom of the page, more the scale up to the top of the next column so you may continue there. Also, scale alignment is not critical.

Selection Without Replacement

Selection without replacement means that once an individual number is selected it is not placed back in the population and may not be selected again. In this case step 8 is changed to:

STEP 8: If a number is selected more than once, call that number only once and record the results only once. Every other time it gets selected ignor it and skip to the next page number in the table and return to step 3.

Choice of Method

From a statistical point of view, when the population is large compared to the sample size it does not make much difference whether selection is made with or without replacement. As the population size decreases relative to the sample size the difference is important. For simplicity of analysis the with replacement method is preferred.

Alternative Procedures

The first sentence of this section indicated that only persons listed in the telephone directory should be contacted for survey purposes. This restriction is currently in effect mainly because of the belief that one reason a person has an unlisted number is because he does not want to be bothered with surveys and other nuisance calls. People may often view a government survey more favorably than commercial ones and be less distressed by them. Furthermore, just because a person's number is listed does not mean he will not be irritated by survey calls. Given all these considerations the PUCO may wish to consider lifting that restriction. If the restriction is lifted, random telephone numbers for the 10,000 line, mostly filled, offices may be more easily generated. Table V can be used for this purpose in the following way:

STEP 1: Choose an arbitrary starting point in any row, column, and page of Table V.

STEP 2: Dial the prefix for the central office being surveyed, then dial the 4 digit* number from the table.

STEP 3: Select all remaining numbers successively by moving first across the page and then down as if reading.

COMMENT: If there is more than one prefix in the central office the number of contacts to subscribers on each prefix should be proportional to the number of lines in each office. For example, suppose the following information is available on the office:

PREFIX	LINES	% FILL
486	9229	92.3
488	7381	73.8
481	1620	16.2
total	18230	

Also suppose 25 contacts are to be made, then

*Those with less than four digits should be filled to four digits with leading zeros.

25·(9229/18230) = 13* contacts should be made to 486 subscribers,
25·(7381/18230) = 10 contacts should be made to 488 subscribers, and
25·(1620/18230) = 2 contacts should be made to 481 subscribers.

It should be noted that if less than 70% line fill is present on any prefix it is a good idea to obtain those numbers from the white pages as described earlier in this section since many of the numbers generated in Table V would not be in service. Under such circumstances this method will require excessive dialing.

* Any number with fraction greater than or equal to .5 should be rounded up and all others rounded down.

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