THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 61, No. 6, July–August 1982
Printed in U.S.A.

Automated Repair Service Bureau:

Economic Evaluation

By E. A. OVERSTREET

(Manuscript received March 3, 1981)

Throughout the conception, development, and deployment of the Automated Repair Service Bureau (ARSB) systems, economic studies have played a continuing and important role. Prior to the development of ARSB, economic studies quantified the potential costs and benefits, leading to the funding of the ARSB project. Throughout the ARSB development phase, the economic studies were refined and used to influence system features. Several field trial evaluations were conducted in Bell Operating Companies (BOCs) to verify the economic models and to refine operational procedures. Prior to system availability, economic planning guides for Loop Maintenance Operations System (LMOS) and Mechanized Loop Testing (MLT) were generated to assist the BOCs in planning for the implementation of ARSB. This article describes the purposes, methods, and results of each of these economic activities. Currently, approximately 75 percent of the Bell System lines are served by LMOS and 50 percent by MLT. Significant reductions in repair expenses, as well as flexibility in the organization of maintenance centers, have been achieved as a result of ARSB development.

I. INTRODUCTION

Throughout the conception, development, and deployment of the Automated Repair Service Bureau (ARSB) systems, economic studies have played a continuing and important role. As shown in the economic "flow chart" in Fig. 1, economic studies are used to

(*i*) help identify the need for a new system,
(*ii*) lead to a decision to develop a new system,
(*iii*) influence system requirements,

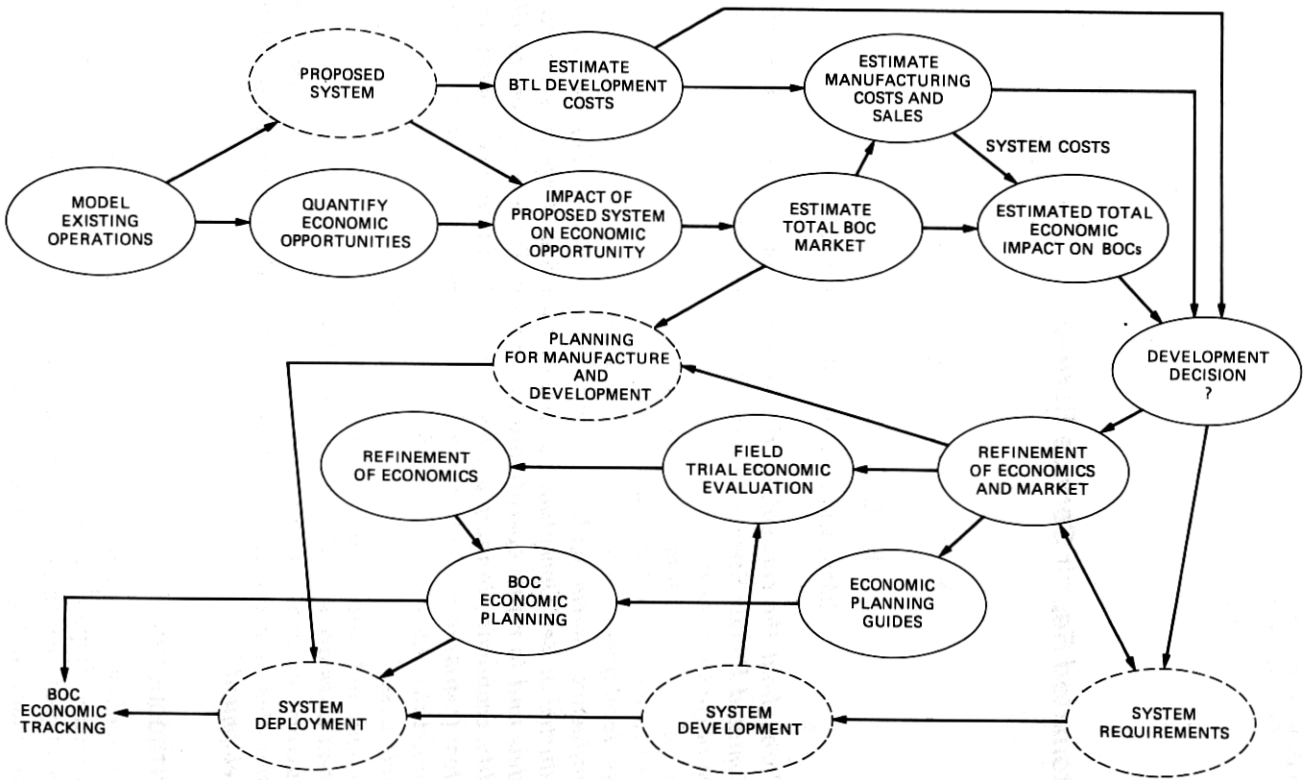

Fig. 1—Role of economic analysis in the life of a system.

(*iv*) support the supplier in pricing and planning for manufacture and/or implementation, and

(*v*) support BOC planning for system implementation.

During the planning and development of Loop Maintenance Operations System (LMOS) and Mechanized Loop Testing (MLT) system, three major economic milestones occurred. These were (*i*) the economic summary support to the Western Electric Case Authorization which led to the funding of ARSB, (*ii*) the publication of LMOS and MLT Economic Planning Guides, and (*iii*) economic results from field-trial evaluations. In addition, there were refinements of the economic analysis throughout the ARSB program.

Section II of this paper describes in more detail the purposes, methods, tools, and results used in each step of the ARSB economic evolution. Sections III and IV provide detailed models of costs and benefits for LMOS and MLT.

Additional ARSB modules include the next generation of both LMOS and MLT, plus the LCAMOS systems. The economic analysis of these systems are not discussed in this paper. However, the economic analysis methods discussed for LMOS and MLT apply to the newer systems.

The reader is encouraged to read the introductory article of this issue of *The Bell System Technical Journal* for background on the loop maintanenace process and an overview of the ARSB systems.

II. EVOLUTION OF ARSB ECONOMIC STUDIES

In this section, the role of economic studies in each step of the decision-making processes involved in defining, developing, manufacturing, and deploying LMOS and MLT is discussed. The evolution of ARSB economic studies discussed in this section covers a time span of approximately ten years.

2.1 Early estimates—support development decision

In 1968, a Repair Service Bureau (RSB) Task Force warned that unless mechanization is introduced to the repair process, the cost of repair service operations would increase at a rapid rate, because of Bell System growth and increasing labor rates, and that service to the customer would degrade. As a result of their studies, they recommended that loop records be computerized, improved testing equipment be developed, and repair service record keeping and analysis be computerized.

The next step was to model the costs required to perform the loop maintenance function in sufficient detail to allow estimates of opportunities for economic benefits. By gathering and analyzing data on the costs required to test trouble reports, to maintain the manual line record files, and to dispatch repair craft resulting in no trouble being found, it was estimated that significant benefits might result from mechanization. The economic benefit model was then refined concurrently with the formulation of a conceptual system which appeared both technically and economically feasible. A conceptual system was first proposed in a Prospectus for New Methods and Equipment for Exchange Special Services and Local POTS Testing Systems in 1971. The economic benefit model was refined by visiting a number of Bell System RSBs and modeling their existing costs. The estimated economic impact of the proposed new system was incorporated into the economic model and both the potential benefits (i.e., reduced maintenance expenses) and the cost of the system for a typical BOC "installation" were derived.

The next step was to extend the "typical installation" economics into a Bell System view which assessed the economic impact of the proposed system on all of the BOCs. Market data were gathered from a survey which included statistics on the number and sizes of all BOC RSBs and distribution of wire center sizes. Also required were estimates from Western Electric on the costs to manufacture, sell, install, and support the system, as well as estimates of Bell Laboratories development costs. The total Bell System economic impact was then analyzed and a development decision was made based upon net economic savings to the BOCs, projected Western Electric sales and required Bell Laboratories resources. The initial request for development funding was submitted in 1973.

2.2 Market studies

Inherent in the estimate of the total economic impact of ARSB on the BOCs is an estimate of the potential penetration of ARSB in the BOCs. However, the market studies have value beyond that of simply supporting the development decision. In particular, market studies are used for the following purposes:

(*i*) To serve as a basis for the software supplier to develop a pricing strategy to ensure that early customers are charged properly and that the supplier recovers its development costs.

(*ii*) To serve as a basis for the hardware manufacturer to estimate the manufacturing capacity that must be planned and implemented.

(*iii*) To serve as input to the system design requirements for those features that are sensitive to the market characteristics.

The market estimates for LMOS were rather straightforward. It was assumed, and is still expected, that all BOCs would install LMOS. In addition, it was also assumed that each BOC would serve all of their lines with LMOS. This later assumption was based on

(*i*) the high initial cost of LMOS (e.g., for host computer, front-end processers, conversion process) and the low incremental cost to add lines, and (*ii*) the desire for consistency within a BOC in receiving trouble reports, tracking reports, and post-trouble analysis—all of which are significantly impacted by LMOS.

Using estimates from the LMOS developers of the capacity of the LMOS computers, the number of host and front-end computers was derived from the total number of lines in each BOC. Allowances were made for growth and for special data processing administrative boundaries within some BOCs. These estimates were made originally by Bell Laboratories and Western Electric and then updated as the BOCs started formulating their own LMOS deployment plans.

Estimating the potential market for MLT was more complicated, primarily because there are no large initial centralized costs for MLT and each wire center in a BOC must be examined individually to determine whether it can economically justify MLT. Also, unlike LMOS, MLT does not impact the procedures for processing trouble reports significantly enough to create a desire for universal deployment. In other words, it is not economical for MLT to cover all sizes of wire centers in the Bell System and the individual BOCs deployed it selectively. Furthermore, since a single MLT system can test several wire centers if they are all located within MLT testing range (approximately eight miles), wire center data alone are not sufficient to estimate the number of MLT systems required. The geographical clustering and trunk routes between wire centers must also be known. The first step in the MLT market estimate was to model the costs and potential benefits of MLT to determine the number of lines required in a wire center cluster for MLT to be economically justified. This threshold was used as a guideline but may vary significantly from BOC to BOC depending on trouble report rates, dispatch strategies, travel times for repair and RSB consolidation plans. The next step was to examine several BOCs in detail to determine the impact of wire center clustering on the ratio of MLT systems to wire centers. These ratios were then applied to a distribution of wire center sizes for the Bell System, and an estimate of total MLT market was derived.

As of the end of 1980, 18 BOCs had implemented LMOS with approximately 50M lines being served, and 14 BOCs had initiated their MLT implementation serving approximately 25M lines. It is estimated that by the end of 1983, all lines in the Bell System will be served by LMOS. The deployment of MLT, expected to eventually serve approximately 85 percent of the Bell System lines, is expected to be completed in the mid-1980s.

2.3 Economic planning guides

The ARSB system requires a significant investment by the BOCs and impacts their maintenance procedures. Therefore, to be ready to deploy ARSB when it became available and to realize the system benefits, the BOCs began their ARSB planning at least two years before actual system deployment. Economic planning guides for LMOS and MLT, produced by Bell Laboratories, were essential to this planning process. The purposes of the two planning guides were to

(*i*) provide guidelines for each BOC to size the LMOS and MLT systems to meet their application requirements,

(*ii*) allow each BOC to estimate LMOS/MLT costs and benefits for their particular operating environment,

(*iii*) support the BOC planning and budget process to ensure that the required ARSB investment is included in the corporate budget, and

(*iv*) allow BOCs to estimate changes in their personnel (both numbers and types) in advance of system deployment.

The format of the two planning guides followed the general outline given below:

(*i*) Systems architecture showing the relationship of system components, the modular flexibility in sizing these components and the restrictions on the capacity of each component. (For example, Fig. 2 shows the ARSB computer hierarchy, Fig. 3 illustrates the modularity of the MLT testing hardware, and Table I gives the restrictions on the MLT hardware and controller.)

(*ii*) Definition of BOC data required as input to the planning guide, e.g., RSB and wire center parameters, such as lines served and trouble report rates.

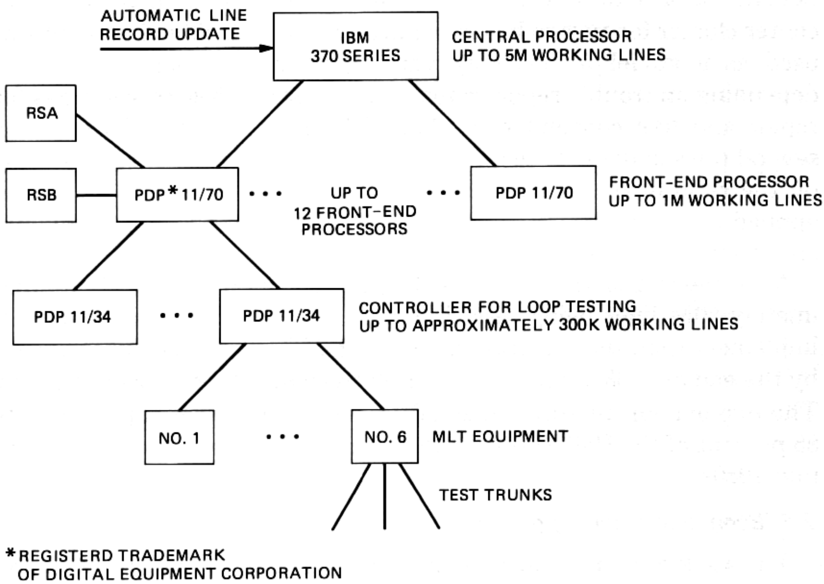

Fig. 2—Automated Repair Service Bureau architecture.

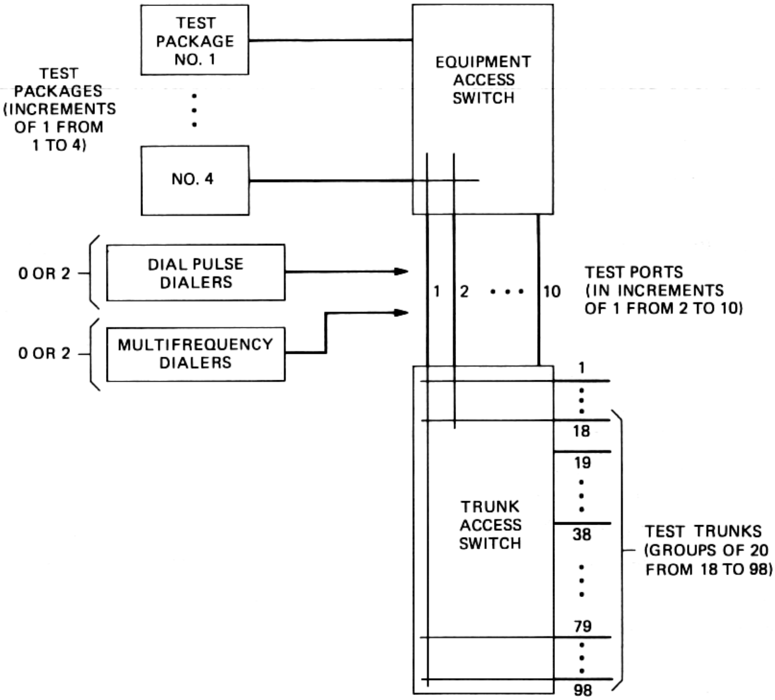

Fig. 3—Modularity of MLT hardware.

Table I—Restrictions on MLT application

MLT hardware	
Maximum number of test trunks	98
Tests per busy hour	600 maximum
Distance limitation (test trunk and loop)	3000 ohms or 100 kft
MLT controller	
Maximum number of MLT frames	6
Maximum number of test trunks	120
Maximum number of exchange codes	40
Maximum number of tests in busy hour	600

(*iii*) Model of the system costs and benefits with procedures for applying the BOC data to these models.

(*iv*) Sizing guidelines for determining the amount of modular equipment (e.g., front-end computers, terminals, MLT controller, etc.) required for each specific application of the system.

(*v*) Worksheets for use by the BOCs to size the LMOS and MLT equipment and to estimate costs and benefits using their input data.

One of the more critical parts of the planning guide discussed above is the generation of equipment sizing guidelines. These guidelines address two opposing objectives; to minimize the amount of equipment (and hence the cost) that the BOC must purchase while providing sufficient equipment to respond quickly to test requests.

The equipment sizing guidelines were particularly sensitive to two parameters: holding times for each piece of equipment and the number of MLT test requests generated by a given population of lines served. The holding times were originally estimated by the developers and used in the planning guides. During the MLT field trial, equipment holding times were monitored using computer log tapes and the sizing guidelines were updated to reflect the actual holding times. Originally, equipment-sizing requirements were provided to the BOC as a function of number of lines served by the equipment. This assumed a relationship between lines served, trouble reports, and MLT tests per trouble report. As the BOCs implemented and started using MLT, it was found that MLT usage varied among the BOCs depending on operational procedures. As a result, the equipment sizing tables were revised to provide equipment sizing requirements as a function of lines served, trouble reports, and expected MLT tests per hour, as shown in Table II.

For LMOS, the planning procedure was basically a straightforward pyramid approach. The approach was to do the following:

(*i*) For each RSB, Centralized Repair Service Attendant Bureau (CRSAB), and training center, determine the number of I/O terminals (CRTs and printers), number of lines served, I/O ports required on the front-end processor, and the transaction rate, based on trouble report and service order activity.

(*ii*) Determine number of front-end processors required, taking into consideration processor limits on I/O ports, lines served, and transaction rates.

(*iii*) Allocate RSBS, CRSABS, and training centers to specific front-

Table II—MLT Equipment sizing guidelines

	MLT Tests Per Busy Hour	Trouble Reports Per Busy Hour	Lines (1000)
Test trunks			
1	<6	<3	<3.5
2	6–43	3–22	3.5–30
3	43–110	22–60	30–80
4	110–185	60–100	80–130
Test ports			
2	<20	<10	<15
3	20–65	10–35	15–45
4	65–145	35–75	45–100
5	145–225	75–115	100–150
6	225–300	115–155	150–210
7	300–390	155–200	210–270
8	390–480	200–250	270–330
9	480–570	250–300	330–400
Test packages			
1	<20	<10	<15
2	20–145	10–75	15–100
3	145–390	75–200	100–270
4	390–580	200–300	270–400

end processors so that the limits of no front-end processor are exceeded.

(*iv*) Determine the number of host computers required and allocate front-end processors to hosts.

For MLT, the process flow was similar but could require several iterations to minimize overall MLT costs. This was due to the flexibility that the BOCs had in clustering wire centers on MLT hardware and in assigning MLT hardware to MLT controllers to achieve a balance on controller load in terms of LTFs, NNXs, test trunks, and testing load (i.e., see Table I).

The initial planning guidelines provided a fundamental model for sizing the LMOS and MLT systems and for estimating costs and benefits. As changes in configurations, costs or sizing guidelines occurred, the BOCs were notified either directly by Western Electric (prices) or via an ARSB Equipment Design Requirement which has been periodically updated and reissued by Bell Laboratories. However, the planning procedures used in the Economic Planning Guides are still applicable.

2.4 Refinements of economic estimates

As LMOS and MLT were being developed and deployed, the projections of system costs and benefits were periodically reevaluated as new data became available and the system configuration and features were becoming firmer. Included in these economic evaluations were (*i*) revised MLT benefits as a result of experimenting with an early model of MLT in a real operating environment in 1974, (*ii*) revision of LMOS and MLT benefits based upon pretrial characterization data gathered in the MLT trial site in 1975, and (*iii*) revision of LMOS/MLT benefits based upon data gathered from 15 BOCs in 1977. The results of the latter two studies will be discussed in more detail in Sections III and IV.

To gain experience with MLT in an environment of real trouble reports, an experiment was arranged to use an early model of MLT in several RSBs. Objectives of this experiment were to show that MLT could be useful in a functioning RSB, to gather data to refine MLT testing strategies, and to refine the projected MLT economic benefits. The experiments demonstrated that more than 80 percent of the troubles entering the RSB could be processed using only MLT test results; i.e., less than 20 percent would require local test desk testing. Direct benefits observed for MLT were less manual testing, fewer and more accurate dispatches, and the possible immediate close-out of some trouble reports as test-okays at the time they are received.

Throughout many of the ARSB economic studies, computer programs were used to mechanize much of the manipulation of economic data. These programs provided the user with standard and consistent treatment of such variables as taxes, depreciation, salaries, cost of money, inflation rates, and calculations of conventional economic results, such as discounted cash flows, net present value of savings, rate-of-return on capital, and discounted payback periods.

2.5 Field trial results

Before deploying LMOS and MLT in the total Bell System, field trials or evaluations were conducted to ensure that the systems were viable in an operating environment and to refine the economic benefits and cost estimates for the systems. Three field trials or evaluations were conducted on the ARSB system:

(*i*) An evaluation by Bell Laboratories of the first installation of the Mechanized Line Record (MLR) system, a predecessor to LMOS which contained many of the features of LMOS, but with a different computer architecture, in 1973.

(*ii*) An operational and economic review by AT&T, with assistance from Bell Laboratories, of the first LMOS installation in 1975, and

(*iii*) A field trial of the MLT system in 1978.

2.5.1 Mechanized Line Record system evaluation

The general operational conclusions of the evaluation were as follows:

(*i*) The MLR system handled the work load in the trial RSB in a fashion acceptable to the users.

(*ii*) Service to the RSB customers appeared to improve with MLR.

(*iii*) A reduction in work force was possible with MLR.

Economic benefits for MLR were estimated from the evaluation as follows:

(*i*) Reduction in clerks previously required to update and maintain the manual line record file.

(*ii*) Savings in trouble tickets and associated computer costs to perform trouble analysis.

Thus, economic benefits were observed, with a possible additional benefit if the clerical labor required to manually update the MLR mechanized records could be eliminated. This potential benefit led to the development of an automatic interface between the LMOS system and the service order network.

2.5.2 Loop Maintenance Operation System evaluation

A performance evaluation of the first LMOS system was conducted by AT&T Customer Services and Data Systems organizations during 1975. The evaluation encompassed eighteen RSBs, the first of which was converted to LMOS in 1975, and one Centralized Repair Service Attendant Bureau (CRSAB) serving 1.3 million lines. Evaluation methods involved the use of questionnaires, interviews, and the examination of pertinent data and reports. Among the specific areas reviewed were system performance, service and cost benefits, data conversion efforts, documentation, and employee acceptance of the system.

In the area of cost and benefits, the evaluation report indicated that the economic benefits attributed to LMOS in the LMOS Economic Planning Guide were substantiated. Specifically, a large reduction in the clerical force had been realized from the employment of the CRSAB concept and the elimination of clerical activity associated with line card maintenance. Additionally, substantial net capital savings was realized in recovered plant as the line records and assignment data were purified for entry into LMOS. However, these savings were not universally claimed for LMOS since it was recognized that other areas may not obtain comparable savings since these savings are a function of growth rate and present condition of plant records.

In summary, the evaluation team concluded that "LMOS is facilitating improved RSB administration in addition to providing substantial economics—we recommend that the BOCs proceed with their implementation plans."

2.5.3 Mechanized Loop Testing field trial

The objectives of the MLT field trial were (*i*) to verify and refine the projected economics for MLT, (*ii*) to refine the operational use of MLT, and (*iii*) to provide feedback to the developers on system changes and proposed enhancements. More of the verified benefits came from RSB savings (i.e., tester reduction) and less from a reduction in outside repair forces than was predicted in the model in Section 4.1. This difference between the predicted and verified sources of MLT benefits was due, in part, to the introduction of a successful Repair Force Management plan in the RSB prior to the MLT trial but after the initial MLT benefit estimate. The Repair Force Management program yielded a reduction in repair dispatches at the expense of additional testing in the RSB; thus, increasing the opportunities for MLT benefits in the RSB, while decreasing the possible MLT benefits in the repair force area.

The major impact of MLT was to eliminate two of the seven testers in the 70,000-line RSB. With the introduction of MLT, the percent of trouble reports requiring testing at a local test desk was reduced from 70 percent to less than 15 percent. Of the remaining five testers, only one was required for trouble report testing; the other four performed cable testing and dispatch, construction testing (e.g., cable throws) and interactive testing support of repair craft in the field. After the official MLT trial ended, it was possible to further deload the test desk to two testers by having screening clerks and dispatchers, using MLT, test cable throws and provide much of the testing support to the repair craft in the field.

In the area of reduced dispatches, the primary contribution of MLT was that it allowed dispatchers, with no testing experience, to perform a quick MLT test on a trouble immediately before it was dispatched. Using this "predispatch" testing, troubles that had "come-clear" between the time of the initial test and the time of dispatch could be closed out without dispatching, thus, avoiding a dispatch which would have resulted in no trouble being found. In addition, MLT was able to accurately detect Receiver-Off-Hook (ROH) conditions and avoid dispatches on these nontrouble conditions.

An additional benefit was projected based on MLT's ability to identify some cable problems (and, thus, avoid an initial dispatch of a station repair craft) and to provide distances to an open cable fault. This benefit would be realized in an environment where station repair forces are restricted from working in the cable plant.

In summary, the more important results from the MLT field trial evaluation were as follows:

(*i*) The projected benefits of MLT (Section 4.1) were substantiated.

(*ii*) The MLT system provides accurate measurements of the electrical characteristics of both good and faulted loops, as measured from the central office.

(*iii*) The RSB personnel readily adapted to the MLT system after receiving the prescribed training and gaining confidence in the accuracy of the system.

(*iv*) The MLT system and its operational use were improved because of changes and refinements throughout the trial period.

(*v*) Since MLT tests could be initiated from any LMOS console and most (>85 percent) of the MLT test results could be interpreted without testing experience, RSB testing functions could be distributed throughout the RSB rather than confining them solely to the local test desk.

III. LOOP MAINTENANCE OPERATION SYSTEM BENEFIT/COST MODEL

3.1 Loop Maintenance Operation System benefits

The methodology used in the estimate of LMOS benefits was as follows:

(*i*) The major clerical functions performed in an RSB were identified by interviewing RSB managers and observing operations in several RSBs,

(*ii*) The time (expense hours) required to perform each of the identified clerical functions was modeled based on detail data gathered over intervals ranging from two weeks to three months in 15 selected RSBs throughout the Bell System,

(*iii*) The impact (percent reduction in required hours) of LMOS on each of the clerical functions was estimated by comparing the features of LMOS with the clerical functions, (*iv*) Resultant reductions of whole people were estimated based upon the reduction in required hours because of LMOS and the regrouping of remaining clerical functions into reasonable job positions.

Each of these steps is discussed with quantified results in the following sections:

3.1.1 Clerical functions

The major clerical functions performed in a manual (i.e., pre-LMOS) RSB are described below. The relationship of five of the seven functions to the overall trouble processing flow in the RSB is illustrated in Fig. 4.

(*i*) *Receiving trouble reports*—Includes customer contact and generation of trouble ticket.

(*ii*) *Line card activity on trouble reports*—Pulling line card, attaching to trouble report, recording trouble data on line card, and filing of line card when trouble is closed out.

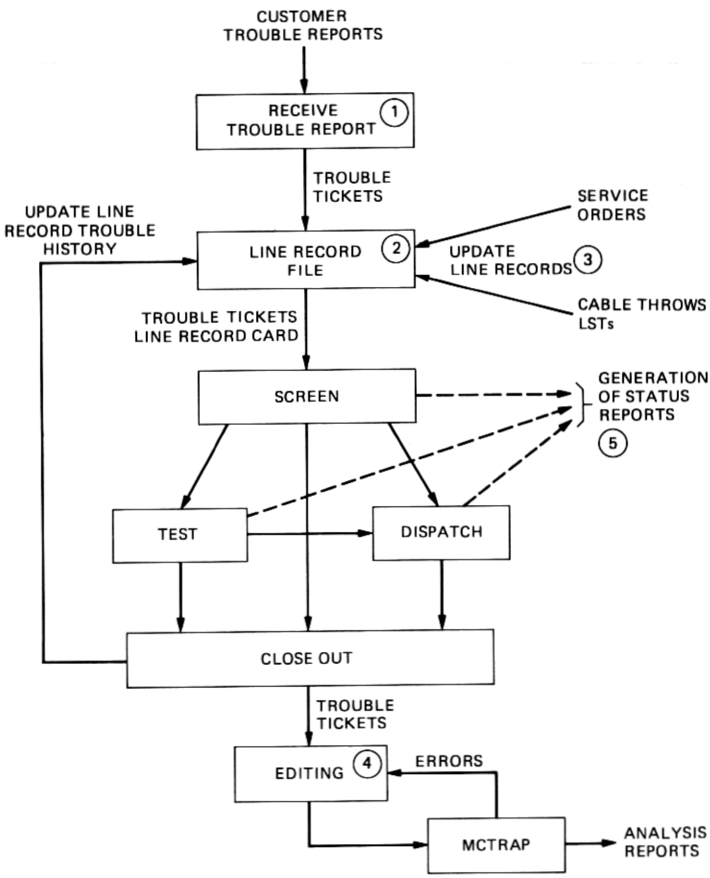

Fig. 4—Repair Service Bureau trouble report processing.

(*iii*) *Service order processing*—Updating of line record information in response to service orders, line and station transfers, cable throws, and service denial/restorals.

(*iv*) *Preparation of trouble tickets for analysis by the Mechanized* Trouble Report Analysis Program (MCTRAP)—editing of tickets for proper coding and correction of tickets rejected by MCTRAP.

(*v*) *Generation of reports*—Includes the generation of RSB work load status reports, reports of service times, and numerous other reports.

(*vi*) *Handling information requests*—Checking line cards or trouble tickets to answer requests for assignment information and trouble status.

(*vii*) *Miscellaneous*—Includes all minor functions not identified in other categories.

3.1.2 Time required to perform functions

To quantify the time spent on each of the above functions, repair clerks in 15 RSBs were asked to charge their time to one of the above functions for a period of from two weeks (in most RSBs) to three months in a few RSBs. Table III shows the percent of total clerical hours spent on each of the major clerical functions. The average RSB in the Bell System had approximately one clerk per 9K lines served, so a typical 70K line manual RSB would require eight repair clerks. In Table III, the percent of clerical hours can be translated into equivalent people, with partial people per function being completely reasonable, since a single clerk may perform several functions throughout the day.

3.1.3 Estimated impact of LMOS

The next step was to estimate the impact of LMOS on each of the clerical functions which could be affected in varying degrees by LMOS. The impact of specific LMOS features upon each of the clerical functions is discussed below:

Table III—Distribution of RSB clerical functions and estimated LMOS benefits

Function	Percent Clerical Hours	Percent LMOS Impact	Percent LMOS Reduction
Receiving trouble report	34	25	−9
Line card activity	23	100	−23
Service order processing	10	50	−5
MCTRAP preparation	7	100	−7
Report generation	8	50	−4
Information requests	9	50	−4
Miscellaneous	9	25	−2
Total reduction			−54
Assume reduction of 50 percent manual clerical hours.			

(*i*) *Receiving trouble reports*—LMOS provides customer line record information to the Repair Service Attendant (RSA) during the customer contact and provides for entering trouble report information directly into LMOS, thus, eliminating the manual trouble ticket. In addition to improved customer service, the absence of manual line records and trouble tickets allows the RSAs to be physically separated from the RSB responsible for clearing the customer's trouble. This allows for centralization of RSAs, thus, allowing improved balancing of personnel and work load, particularly for night and weekend coverage of trouble calls. Once the trouble report is taken at the centralized location (typically serving one million or more customers), the LMOS system automatically prints out the trouble report and associated customer record information in the responsible RSB.

(*ii*) *Line card activity on trouble reports*—The line record data base in the LMOS computer completely eliminates this manual function.

(*iii*) *Service order processing*—A large percentage of service orders (i.e., the simpler orders) are processed by the Automatic Line Record Update (ALRU) module of LMOS and automatically updates the line record data base in LMOS. Some manual update effort is required with LMOS to input via a CRT transaction the more complex (e.g., large business) service orders and to update the line record data base for cable throws and line-and-station transfers.

(*iv*) *Preparation of trouble tickets for analysis*—The Trouble Report Evaluation and Analysis Tool (TREAT) module of LMOS provides a comprehensive trouble analysis program using the trouble report data collected within LMOS. Thus, LMOS completely eliminates the paper trouble tickets and the previous analysis tools.

(*v*) *Report generation*—Each person (e.g., screener, tester, dispatcher, etc.) that handles a trouble report enters into LMOS the current and pending status of the trouble. The LMOS can then generate status and jeopardy reports which provide a snapshot of the work load at any position in the RSB and for the outside repair craft. This significantly reduces the clerical effort involved with status reports.

(*vi*) *Information requests*—Because LMOS contains the latest customer line record information, the status of open trouble reports, and abbreviated trouble history for each customer; information requests can be handled much quicker by the RSB clerical forces.

(*vii*) *Miscellaneous*—The more efficient RSB operation provided by LMOS will have some benefit in the miscellaneous functions.

3.1.4 Quantifying LMOS benefits

The estimated reduction in RSB clerks because of LMOS is summarized in Table III. Of the clerks required in the manual RSB, approximately 50 percent could be eliminated by LMOS. Of the remaining clerks, one-half would be transferred to a CRSAB for receiving trouble calls and the other remaining one-half would either remain in the RSB or in a data base management group to process LMOS line record updates not handled by ALRU and for miscellaneous RSB clerical functions.

In addition, there will be a reduction in first-line managers and the elimination of expenses associated with the paper trouble ticket and the computer processing previously required to perform trouble report analysis.

3.2 Loop Maintenance Operations System cost model

The calculation of costs and benefits expressed in terms of measures like the cash flow on a yearly basis and including such effects as inflation, tax treatment, accelerated depreciation rules, etc., requires the use of an economic analysis software tool.

The LMOS cost components can be divided into three major categories:

(*i*) Initial capital costs, e.g., purchase of PDP* 11/70 minicomputers,

(*ii*) Initial expenses, e.g., initial data conversion and loading expenses, and

(*iii*) Annual expenses, e.g., data processing labor.

Each of the above categories can be converted into equivalent annual charges by applying appropriate conversion factors based upon cost of money, depreciation rates, etc.

IV. MECHANIZED LOOP TESTING BENEFIT/COST MODEL

4.1 Estimated MLT benefits

The purpose of this section is to illustrate the type of data and methodology used in the earlier estimate of MLT benefits. As discussed previously in Section 2.5.3, the MLT field trial generally confirmed the total predicted MLT benefits, although the sources of the benefits differed between the predicted model and the trial results. The model of the projected MLT benefits presented in this section is based upon the pretrial data characterization of the MLT trial site, supplemented by lesser amounts of data gathered from 15 RSBs throughout the Bell System.

The expected areas of MLT benefits are listed below:

(*i*) Tester reduction
(*ii*) Reduced repeat reports
(*iii*) Reduced dispatches resulting in no trouble found
(*iv*) Reduced number of station dispatches on cable troubles
(*v*) Reduced trouble locating time for open cable troubles.

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* Registered trademark of Digital Equipment Corporation.

Additional potential areas for MLT benefits, such as the elimination of local test desks and the use of MLT for testing cable throws, may be realizable in some situations but are not included in the benefit model discussed below.

4.1.1 Tester reduction

In the Bell System, there is approximately one tester for each 10,000 lines served. Therefore, in the typical 70K RSB depicted in Table IV, there would be 7 testers with their functions distributed as shown between regular trouble report testing and other testing functions. The distribution of testing functions is based on a sample of 15 RSBs, where the testers recorded the time spent on each of these functions for several weeks. As shown, approximately one-half of the total testing time was spent on trouble report testing prior to dispatch, with the remaining time spent interacting with station repair craft, dispatching, and testing with the cable repair forces and other tasks, such as ALIT testing, testing defective pairs, special service testing, etc. Based on observations of the regular testing function and the testing capabilities of MLT, it was estimated that 15 percent of the troubles will require testing at the local test desk in an MLT environment, compared to 60 percent in a manual testing environment. In an ARSB, one regular tester could handle a busy-day load by testing one trouble every eight minutes. The remaining troubles (85 percent) can be screened and routed by one full-time and one part-time MLT screener, if they maintain an average of screening a trouble every two minutes during the busy hour. Both the testing and screening rates appear to be readily achievable based on observations of testing operations.

4.1.2 Reduced repeat reports

A "repeat" report is defined as a customer trouble report received within 30 days of a previously cleared customer trouble report on the same line. The Bell System repeat report rate is 14 percent of all customer trouble reports. Data gathered on repeat reports in several RSBs revealed that 35 percent of the repeat reports occurred within two days after the supposed clearing of a previous trouble. Thus, it is

Table IV—Tester reduction (in a typical 70K line RSB)

Testing Function	Tester Required	
	Manual	MLT
MLT screener/tester	—	1.5
Regular trouble report testing	3.5	1.0
Interacting with repair	1.0	1.0
Cable testing and dispatch	2.0	2.0
Other	0.5	0.5
Total	7.0	6.0

strongly suspected that the original trouble was not cleared, even though the repair craft may have repaired or changed some equipment. It is estimated that with post-dispatch testing by MLT on the original dispatch, at least half of the repeat reports occurring within two days could be avoided.

4.1.3 Reduced dispatches resulting in no trouble found

The Bell System FOK-OUT rate is approximately 8 percent of all troubles received. In addition, a review of actual repair results from trouble reports indicate that on an additional 2 percent of the troubles no trouble was found on a dispatch, but the trouble was closed to dispositions other than FOK-OUT. Thus, on 10 percent of the trouble reports (equivalent to 20 percent of the dispatches), no trouble was found or repaired by the repair craft.

A distribution of the initial test results of these troubles is shown in Fig. 5. Some of the dispatches on the FOK test results possibly could have been avoided or could have resulted in found troubles because of the MLTS' more sensitive and comprehensive tests. Most of the 100-volt shorts could have been identified by MLT as a receiver-off-hook, thus, avoiding a dispatch. The remaining 23 percent of the troubles which indicated an initial fault would have, in many instances, either been detected as a time-varying fault by MLT or found to have cleared when retested prior to dispatch. Therefore, it is estimated that at least 20 percent of the no-trouble found dispatches could have been influenced by MLT, either by avoiding a dispatch or by helping the repair craft to clear the trouble and avoid a possible repeat report.

4.1.4 Reduced number of station dispatches on cable troubles

Data collected in areas where station repair craft attempted to locate and clear cable faults that were easily assessable revealed that 5 percent of all trouble reports resulted in a dispatch to both a station repair craft and to a cable repair craft before they were cleared. An examination of the test results on these double-dispatch troubles revealed that 40 percent were either open or initially tested okay but

TEST RESULT	PERCENT OF NTFs	
NO TEST	30	
GOOD LINE	40	
100-VOLT SHORT (ROH?)	7	30 (bracketed total)
OTHER SHORTS	5	
GROUND	9	
OPEN	4	
FEMF	2	
NOISE	3	

Fig. 5—Initial test results on dispatches which resulted in no trouble found.

retested open or FEMF once they were dispatched to the station repair craft. With MLT's open fault sectionalization and with retesting prior to dispatch, the initial station repair dispatch on the 40 percent could have been avoided.

4.1.5 Reduced trouble locating time for open cable troubles

In addition to avoiding the initial dispatch of a station repair craft on open cable faults, the MLT open fault sectionalization capability can be used to initially direct the cable repair craft to the area of the fault, thus, reducing the time required to locate the fault. Approximately 16 percent of all trouble reports result in an Outside Plant disposition. However, because some cable faults are cleared by station repair craft and multiple trouble reports can be associated with a single cable fault, the actual ratio of cable repair dispatches to trouble reports is 8 percent, of which 30 percent have been shown to be open. Experience from riding exercises in conjunction with the use of MLT indicates that approximately 15 minutes (out of an average dispatch time of two hours) can be eliminated from the fault locating time on open troubles.

4.2 Mechanized Loop Testing cost model

As was mentioned in Section 2.3, the cost of an MLT installation is sensitive to the number of lines that it serves.

As was described for the LMOS cost model in Section 3.2, the MLT costs can be divided into initial capital costs, initial expenses, and annual expenses. Each of these cost components can then be translated into equivalent annual costs to derive costs on a per-line-per-year basis.

V. SUMMARY

This article has illustrated the evolution of economic studies associated with the ARSB system from the early identification of a need through the development and successful field trial of the system. Based upon this experience covering more than ten years, the following recommendations are presented as being applicable not only to ARSB, but also to other systems either in development or being defined.

The economics of a system must be examined and refined at several stages throughout the definition, development, and deployment of the system. It is not sufficient to perform an economic analysis prior to the development of a system and then assume that these benefits and costs will remain constant. In particular, the continuing economic analysis must be alert to the following:

(*i*) Markets that decrease significantly because of changing BOC environments, technology changes, or alternative product availability.

(*ii*) Benefits that vanish because of changes in functions or the development of other systems that impact benefits.

(*iii*) Increasing system costs.

The economic analysis and market studies must be based upon realistic operational models. Field data characterizing the BOC operations to be impacted by a system should be gathered on-site from several different operational environments. The economic model must address the feasibility and methods for achieving reductions in people. For example, to maximize the number of people reduced by ARSB, some maintenance procedures had to be changed and some work functions redistributed among work positions in the maintenance center.

For systems, such as the ARSB, that require significant capital investments by the BOCs, it is critical that economic planning information be made available to the BOCs as soon as the system features, availability, and approximate cost can be estimated with a reasonable degree of confidence. The budgeting cycle in the BOCs is such that this planning information is typically required at least two years prior to the implementation of the system.