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A PRELIMINARY STUDY OF VARIABLES AFFECTING CALL PROCESSING EFFICIENCY IN A TACTICAL ENVIRONMENT

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ABSTRACT

An initial survey was conducted to identify variables affecting call-processing efficiencyin a tactical communications environment from tape recordings of live switchboard traffic obtained at operational sites in South Vietnam.

The collected data were analyzed to furnish specific information regarding traffic composition, average call-processing times, and operator efficiency.

CONTENTS

TABLES

A PRELIMINARY STUDY OF VARIABLES AFFECTING CALL PROCESSING EFFICIENCY IN A TACTICAL ENVIRONMENT

INTRODUCTION

The need for fast, reliable switching has long been recognized as a prerequisite for an effective tactical communications system. Presumably, optimum efficiency could best be obtained through automatic switching, thus the Army is currently investigating the feasibility of such equipment and related procedures. Even after automated tactical switching is realized, however, there will be a continuing need for manual switching to serve those units whose communications requirements do not justify the speed or sophistication of automated switching or whose mobility requirements would preclude its use. These types of units would still require the inherent flexibility of operator-serviced switchboards.

Although automatic switching would not be appropriate in certain instances, retaining the current family of manual switchboards is not completely acceptable either. They are too slow and tend to form traffic bottlenecks. Accordingly, a new family of cordless manual switchboards is being developed by the Army Area Communications Systems (AACOMS) project manager's office. These new switchboards are being designed for easier and faster operation than present manual boards and are to be implemented where automatic switching is not practical but where there is a definite requirement for high call-handling efficiency.

The Switchboard, Telephone, Cordless, Manual SB-3082( )/GT is an example of the new switchboard. It is a two-wire telephone switchboard of 50-termination capacity and is basically the counterpart of the SB-86/P, a two-wire manual switchboard of 30 terminations expandable to 60 lines.

It has been demonstrated that the SB-3082( )/GT is more efficient, i.e., allows an operator to handle more calls per unit time than the SB-86/P[1]. Although, in any given situation, the SB-3082( )/GT would be expected to outperform the SB-86/P, it is obvious that where traffic density is low, the greater capability of the SB-3082( )/GT would be wasted. Thus, present expectations are that the semi-automatic board will replace the SB-86s at locations where there is a like requirement for circuit capacity but a higher than normal traffic density.

Since a complete replacement of the SB-86s is not currently anticipated, it is desirable to establish criteria for optimal deployment of the new semi-automated equipment. However, before these criteria can be formulated, basic information relevant to the characteristics of the tactical switchboards' working environment is required.

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[1]Phelps, R. M., & Burner, L. R. A study of call processing on the SB-3082( )/GT switchboard. Technical Memorandum 1-69, U. S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Md., 1969.

To gain this type of information, live switchboard traffic data was collected at tactical sites in South Vietnam. These data were then analyzed to clarify three main areas: 1) identification of call-traffic composition; 2) generation of basic information on total call-processing times; and 3) determination of the effects of call type and/or traffic density on operators' call-processing efficiency.

METHOD

The live traffic data was obtained at three operational tactical communications sites which employed the SB-86/P manual switchboard in the 60-termination mode (Fig. 1). The units served by these switchboards were a brigade tactical operations center (Site 1), a division forward base (Site 2), and a brigade headquarters (Site 3). Traffic was monitored for six hours at each site during periods of expected peak traffic. The actual times of day varied and were determined by personnel familiar with traffic patterns at the given site.

Data was collected by connecting a tape recorder in parallel with the switchboard operator's headset position. This arrangement allowed recording of everything the operator heard or said, without physically hindering his normal functions. The operators knew they were being monitored in all cases.

In addition to the tapes, the strip designators indicating circuit termination assignments were obtained for each switchboard along with its trunk routing diagram.

Basically two types of data analysis were performed. The first was purely descriptive in nature and sought to identify traffic composition and system efficiency. This analysis involved categorizing service requests, establishing their relative frequencies and determining their outcomes.

The second approach to the data analysis was to identify operators' call-handling procedures and determine the effects of different traffic conditions. This was done by measuring total call-processing times, reducing these times to component elements, identifying associated operator tasks, and determining operators' performance as a function of call type and traffic conditions.

The raw data was taken from the tapes by repetitive playback. First, each service request was logged in and classified by type and outcome. Then, for each operator-processed request the separate call elements were timed with a stopwatch.

Call Types

Two categories of service request were established: Normal -- subscriber requests called party using the correct call designator; and Information -- caller requests called party using anything other than the proper call designator. In addition, each service request was classified as being a local or trunk request, depending on the intended immediate termination of the call. Calls forwarded to end instruments directly connected to the switchboard were designated local, while

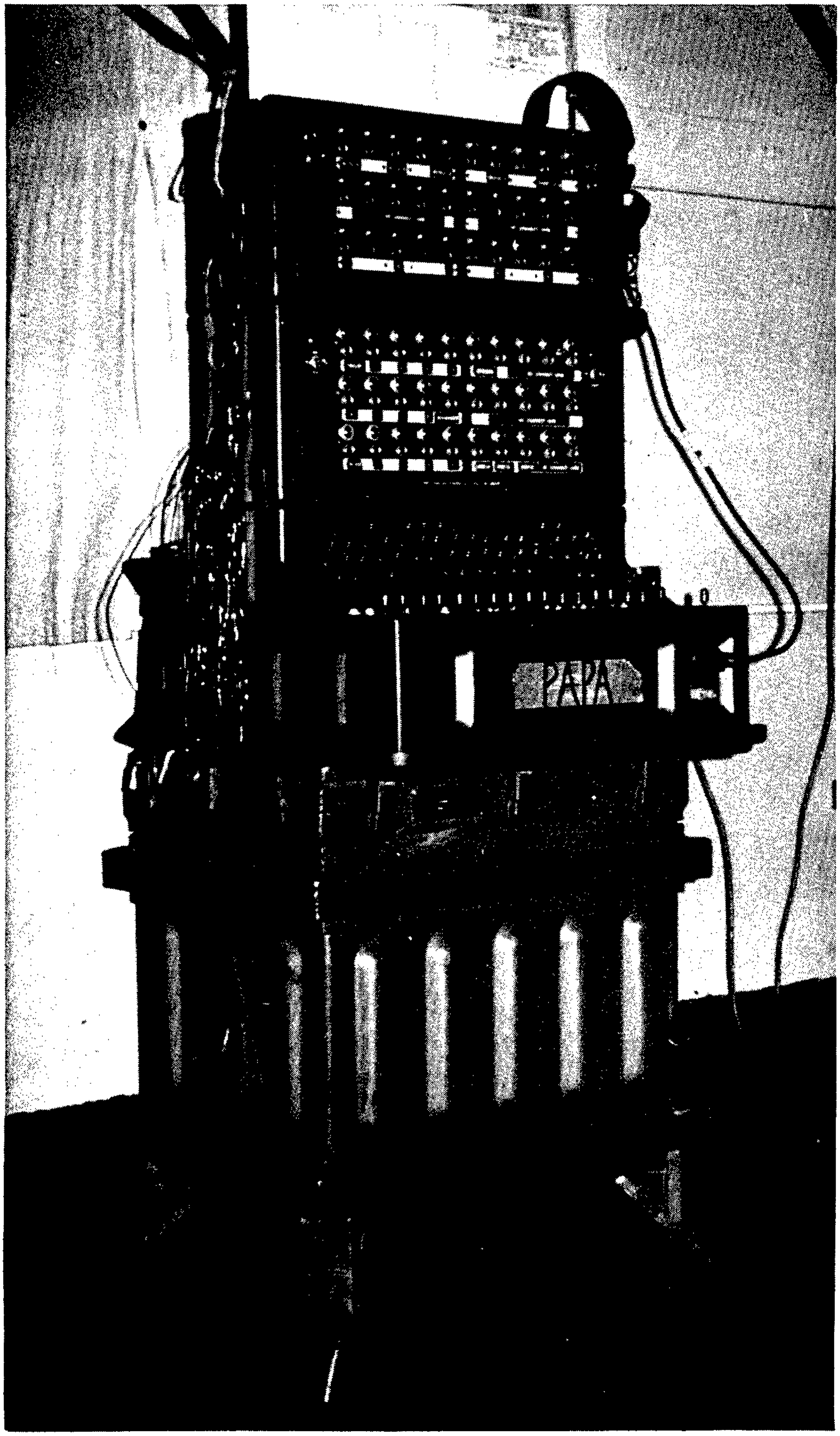

FIG. 1. SB-86/P SWITCHBOARD IN 60 TERMINATION MODE

those directed to another switchboard were designated trunk requests. Thus four basic call types were established, normal local (NL), normal trunk (NT), information local (IL), and information trunk (IT).

Call Outcome

Two possible outcomes of call requests were considered. Either the call was rung forward by the operator or the call attempt was abandoned. (The latter case is typically called an "abort" and can result from either busy circuits or system outages.)

Call Elements

Total time for a completed call request was divided into four discrete segments: 1) Search -- time required for the operator to recognize and acknowledge a service request; 2) Connect -- time for the operator to determine where the call is directed and physically establish the desired connection; 3) Ring -- time the operator spends ringing the circuit forward; and 4) Disconnect -- time the operator spends breaking down the connection when the parties are finished talking.

On the SB-86/P, a service request can occur at any of the assigned terminations. When a calling party signals the switchboard, a line signal (Fig. 2) turns from black to white. (An audible alarm can be keyed to this change in line signal status but its use is optional.) The operator acknowledges the request by moving the cord circuit-switch (Fig. 2) of an idle circuit forward to the TALK/LIST position, plugging the associated answer cord (Fig. 2) into the line jack (Fig. 2) directly below the white signal, and stating the switchboard designator. The caller then states his desired number, and the operator establishes the connection (assuming the circuit is not busy or defective) by plugging the call cord (Fig. 2) into the proper line jack. The operator then rings the circuit several times and finally removes himself by returning the TALK/LIST switch to the neutral position.

When the operator is not extending calls, he monitors the call supervisory signals (Fig. 3) which indicate line status. When one or both of these signals turn white, the operator moves the associated cord circuit switch to TALK/LIST and asks the parties if they are finished. If someone answers, the operator removes himself from the circuit. If no one answers, the operator breaks down the circuit by removing both call circuit cords and returns the cord circuit switch to the neutral position.

Keying these operator functions to the physical manipulation of the switchboard resulted in the following definitions used to quantify call-element times:

a. Search -- time from change in line signal status from black to white to insertion of answer cord;

b. Connect -- time from insertion of answer cord to insertion of call cord;

c. Ring -- time spent ringing the circuit;

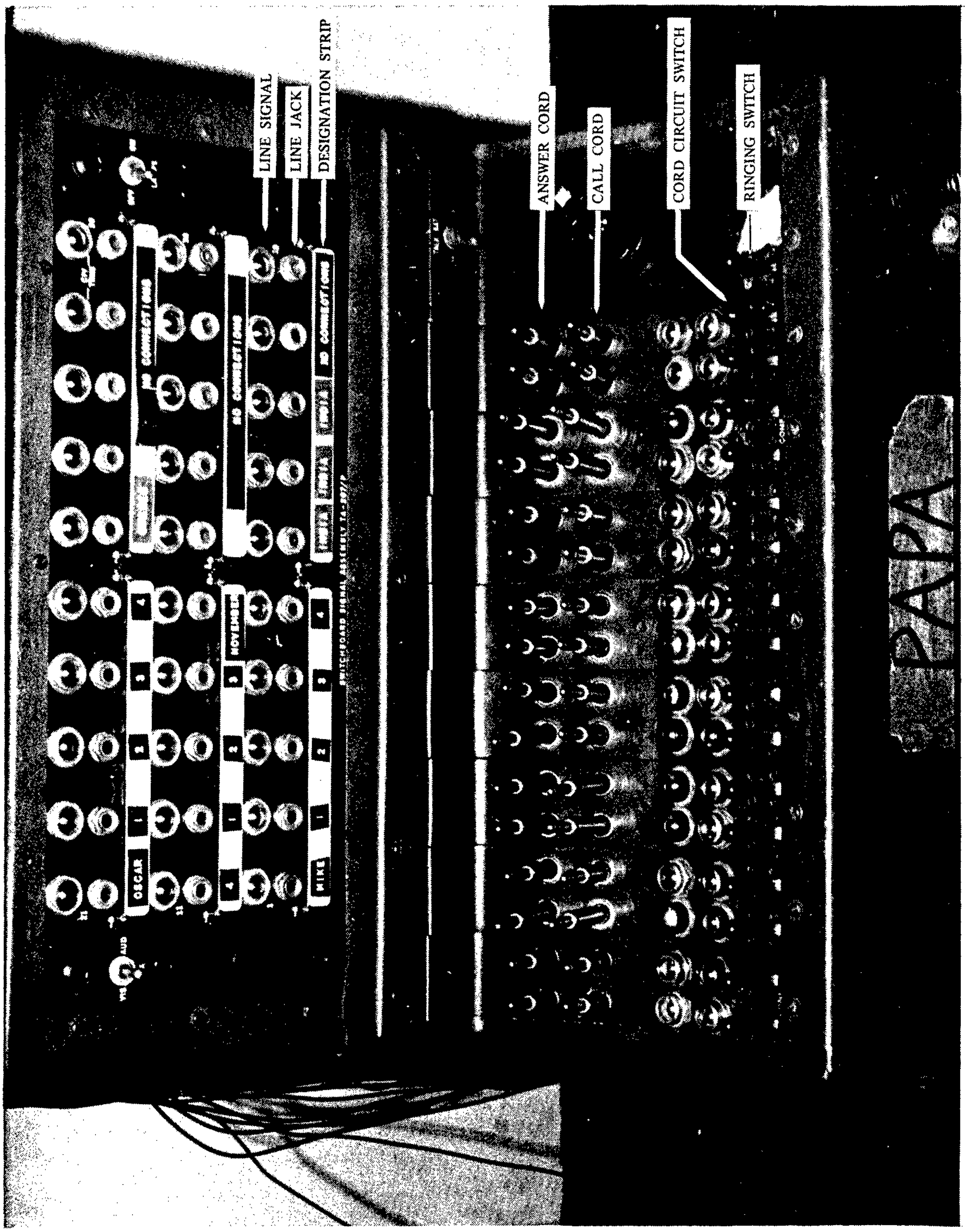

FIG. 2. JACK FIELD SECTION

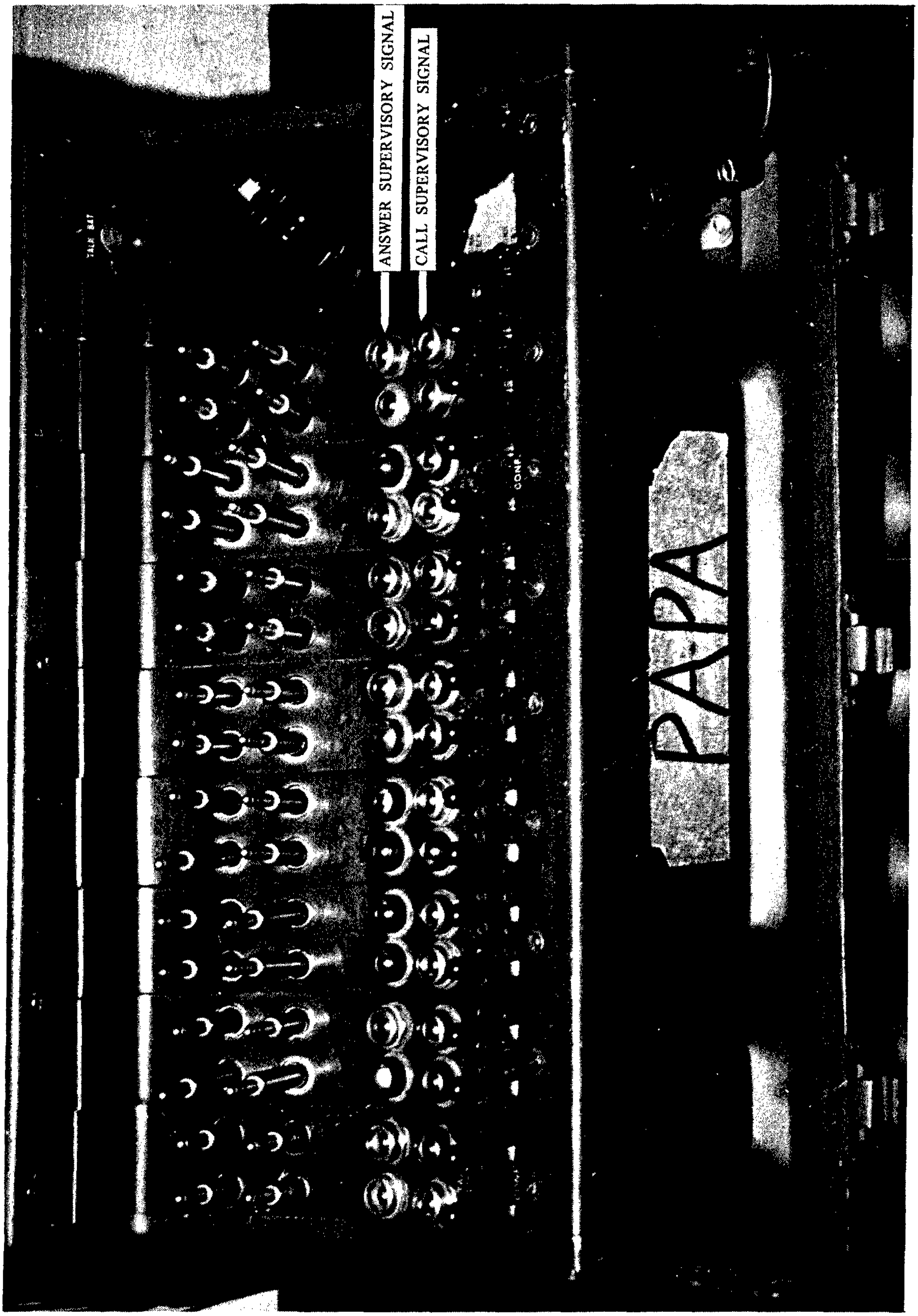

FIG. 3. KEYSHELF SECTION

d. Disconnect -- time from placement of cord circuit switch in TALK/LIST and removal of call cords to return of circuit switch to neutral position.

RESULTS AND DISCUSSION

Traffic Composition

Data was collected on a total of 1067 service requests. A summary of the traffic broken down by call type is presented in Table 1 for each site and as a composite.

TABLE 1

Relative Frequency of Call Types

Site	Total Calls	Call Type NT	NL	IT	IL
1	677	470(69.4)	100(14.8)	39(5.8)	68(10.0)
2	223	140(62.8)	56(25.1)	7(3.1)	20(9.0)
3	167	97(58.1)	40(24.0)	9(5.4)	21(12.5)
Total	1067	707(66.3)	196(18.4)	55(5.2)	109(10.1)

NOTE: Numbers in parentheses are percentages.

As shown, the most common service request was for a trunk circuit (NT + IT = 71.5%), and most requests were placed in the normal manner (NT + NL = 84.7%). Information service requests accounted for only 15.3 percent of the total and most of these were for local circuits.

These profiles are important because they reflect the kind of service the subscriber needs. Whether those needs are anticipated and met largely determines the overall effectiveness of the system.

Circuit Allocation

The switchboard termination assignments for Sites 1 and 2 are presented in Table 2. Termination assignments for Site 3 were lost when the switchboard was relocated.

TABLE 2

Switchboard Termination Assignments

Site	Local	Trunk	Unassigned
1	18 (30.0)	22 (36.7)	20 (33.3)
2	23 (38.3)	19 (31.7)	18 (30.0)
Total	41 (34.2)	41 (34.2)	38 (31.6)

NOTE: Numbers in parentheses are percentages.

As the table shows, 31.6 percent of the known available terminations were not used. Also, of the terminations that were assigned, local and trunk circuits were divided equally. This meant that, on the average, 50 percent of the known allocated circuits were being asked to carry more than 70 percent of the total traffic. Whether this imbalance was a result of poor planning or simply lack of equipment is not known.

Call Outcome

An additional indicator of system efficiency was determined by identifying the outcome of call requests.

A summary of the immediate results of service requests is presented in Table 3.

As shown, 80.1 percent of all call requests were rung forward. Of the 19.9 percent aborted, the majority were prevented by busy circuits. A breakdown of these busy-circuit aborts is presented in Table 4.

TABLE 3

Immediate Results of Call requests

Site	Call Requests	Calls Rung Forward	Calls Aborted	
			Busy Circuits	System Outages
1	677	494 (73.0)	137 (20.2)	46 (6.8)
2	223	207 (92.8)	7 (3.1)	9 (4.1)
3	167	154 (92.2)	12 (7.2)	1 (0.6)
Total	1067	855 (80.1)	156 (14.6)	56 (5.3)

NOTE: Numbers in parentheses are percentages.

TABLE 4

Relative Frequency of Busy Circuit Aborts by Circuit Type

Site	Trunk	Local
1	104 (75.9)	33 (24.1)
2	5 (71.4)	2 (28.6)
3	5 (41.7)	7 (58.3)
Total	114 (73.1)	42 (26.9)

NOTE: Numbers in parentheses are percentages.

As shown, 73.1 percent of all busy-circuit aborts were the result of trunk requests. Since the relative frequency of these aborts is in accordance with the frequency of trunk requests (NT + IT = 71.5%) noted in Table 1, there is good reason to relate the high incidence of busy-trunk aborts to inappropriate circuit allocation. Equally important is the implication that if sufficient communications equipment had been available and utilized a higher degree of system efficiency could have been attained.

A final point suggested by the traffic profiles concerns information calls. Table 5 presents a breakdown of service requests by circuit type.

TABLE 5

Service Requests by Circuit Type

Site	Trunk		Local	
	Normal	Info	Normal	Info
1	470 (92.3)	39 (7.7)	100 (59.5)	68 (40.5)
2	140 (95.2)	7 (4.8)	56 (7.37)	20 (26.3)
3	97 (91.5)	9 (8.5)	40 (65.6)	21 (34.4)
Total	707 (92.8)	55 (8.2)	196 (64.3)	109 (35.7)

As shown, only 7.2 percent of all trunk service requests were information calls. In comparison, 35.7 percent of all local call requests were of the information type.

Table 6 presents information calls separately to better illustrate their relative occurrence.

TABLE 6

Incidence of Information Calls

Site	Trunk	Local
1	39 (36.4)	68 (63.6)
2	7 (25.9)	20 (74.1)
3	9 (30.0)	21 (70.0)
Total	55 (33.5)	109 (66.5)

NOTE: Numbers in parentheses are percentages.

These figures show that of all information service requests (IT + IL), which comprised 15.3 percent of the total traffic (Table 1), 66.5 percent were local calls.

The data presented in Tables 5 and 6 furnish a good picture of user characteristics. Apparently, subscribers tended to be more casual about placing local calls than trunk calls (which are essentially long-distance calls). The exact reasons for this poor user habit are uncertain. It may be the practice is fostered and reinforced by the operators' seeming lack of difficulty in placing the calls and/or failure to complain.

Call-Processing Times

It proved impossible to detect insertion or removal of circuit cords by listening to the data tapes. Also, the manipulations of call circuit switches could not be accurately determined. As a result, call-element definitions had to be modified to allow quantification of search, connect, and disconnect times.

The new definitions were as follows:

a. Search -- time from change in line signal status, accompanied by the night alarm buzzer, to beginning of the operator's statement of the switchboard designator;

b. Connect -- time from beginning of operator's statement of switchboard designator to start of first ring;

c. Disconnect -- time from beginning of operator's initial query of line status to the completion of his statement of intention to break the circuit.

Timing the call elements this way afforded the most reliable means of assessing operator performance without compromising the validity of the measures.

It was also impossible to get measurements of each call element for every call. Search times were obtainable only when the audible night alarm was turned on and typically it was not. Evidently, during heavy traffic the alarm is annoying since it will not stop buzzing while an unserviced call remains on the board. When the service requests begin to overlap, the operator turns off the alarm. This practice was most obvious at Site 1, where out of 677 service requests, only 52 search times were noted. Even where traffic was light, as at Sites 2 and 3, the alarm was not used continuously.

Disconnects presented a different problem. Although not difficult to measure, it was impossible to associate them with any given service request.

For these reasons, no exact total call-processing times could be stated. However, by adding the mean times for each call element, "best" estimates were derived.

Table 7 summarizes the average call-element times (regardless of call type) measured at each of the three sites and also as a composite.

TABLE 7

Average Call Element Times

Site	Search		Connect		Ring		Disconnect		Total*
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	
1	5.9	1.8	6.3	3.4	4.1	1.7	5.3	1.5	21.6
2	5.8	1.2	5.6	2.7	4.4	2.3	5.6	1.1	21.4
3	5.3	1.3	5.4	2.9	3.1	1.3	4.8	0.8	18.7
Composite	5.7	1.5	5.9	3.2	4.0	1.9	5.2	1.3	20.9

NOTE: All times are in seconds

*Best estimates

The figures shown are mean times the operators spent completing the various tasks associated with each call element. The overall "best" estimate of total call-processing time, based on the available data, was 20.9 seconds. Thus, indications are that a single operator could not be expected to process more than three calls per minute or 180 calls per hour. Even this figure is unrealistic since it assumes the operator has no duties other than extending calls. Also not considered is the incidence of aborts which must be handled. We feel that a more realistic estimate of call-processing capability would be about 2.5 calls per minute.

Influence of Call Type on Call Element Processing Times

In determining possible effects of call type on call-element processing times, only connect and ring times could be studied. Search times were not considered because so few were measured and it was feared they might not be representative. Disconnects could not be associated with any call type.

The possibility of significant differences in call-element processing times related to call type was determined by standard t tests. A summary of the comparison of connect and ring times as influenced by call type is presented in Table 8.

Only two of the relationships tested were statistically significant. Connect times for information trunk calls were significantly longer than for either normal trunks or information locals.

The reasons for the significantly longer connect times associated with information calls are fairly clear. Whether consciously or not, the operator memorizes the terminations on his board. In addition, he knows where the circuits go. In the case of a local line, he knows the exact termination and if the subscriber does not use the proper call designator it is no great problem. With a trunk line, the operator knows only an intermediate termination, i.e., another

TABLE 8

Summary of t Tests: Influence of Call Type on Call Element Times

		NT		IL		IT	
		Connect	Ring	Connect	Ring	Connect	Ring
NL	Connect	0.322		0.536			
	Ring		0.675		0.368		
NT	Connect					3.348(.01)	
	Ring						0.850
IL	Connect					3.128(.01)	
	Ring						1.532

t required for significance at .01 level of confidence = 2.576

switchboard. When a caller requests an unfamiliar termination, the operator must ask the subscriber how to get there. The dialogue required to determine the call route is what inflates the connect time.

This line of reasoning is further substantiated by the fact there was no significant difference between information local and normal local connect times.

There were no significant relationships between ring time and call type.

Busy Calls

The time an operator spends handling a busy abort consists of search time and a discussion period during which he explains the nature of the busy circuit. How long the latter takes depends on how much information the subscriber wants. From our data, it was determined the average time spent handling busy calls was 7.4 seconds (σ = 3.6 secs.) or about two seconds longer than the normal search plus connect for a call rung forward.

Traffic Density Versus Call-Processing Times

The average service request rates at the switchboards surveyed were Site 1, 113 calls per hour; Site 2, 45 calls per hour; and Site 3, 33 calls per hour. To study the possible effects of traffic density on operator performance, the data obtained at Sites 2 and 3 were combined and compared with those gathered at Site 1.

Table 9 presents the results of t tests run to compare connect, ring, and disconnect times as a function of traffic density. (Again, not enough search times were available for meaningful comparison.)

TABLE 9

Summary of t Tests: Influence of High and Low Traffic on Call-Element Times

		Low Traffic		
		Connect	Ring	Disconnect
High Traffic	Connect	3.159(.01)		
	Ring		2.119(.05)	
	Disconnect			0.853

t required for significance at .01 level of confidence = 2.576, .05 = 1.960

Two differences were statistically significant. Connect and ring times were both longer in high traffic than in low traffic.

A reasonable explanation for the longer connect times in high traffic is that the operator has greater difficulty finding appropriate line jacks on a crowded board. The greater the number of calls in progress, the greater is the number of call cords being used. Thus, in addition to finding line jacks, the operator often has to separate call cords to make the physical circuit connections. His performance in making connects then can be adversely affected by the location of the line jacks he must service. The feasibility of this type of reasoning is illustrated in Figure 4, which shows an operator in the process of making a connect in a crowded portion of the board.

The factors which caused ring times to be longer in high traffic are uncertain. It would have been more logical to assume that operators servicing boards during low traffic periods would ring circuits longer simply because they had more available time. Since the opposite was true, indications are that the time operators spend ringing circuits is reflexive in nature and highly personalized.

Plug Supervision

Typically, when not extending calls, the operator constantly scans the supervisory lamps (Fig. 3). The purpose of these lamps is to inform the operator of circuit status. When a lamp turns white, it means the connected subscriber has relinquished the line or wishes additional service. In either case, a white lamp tells the operator of the need to query line status.

Theoretically, the operator is not required to check on line status unless alerted to do so by a white lamp. However, since the lamp drops are activated by ringing current, when finished

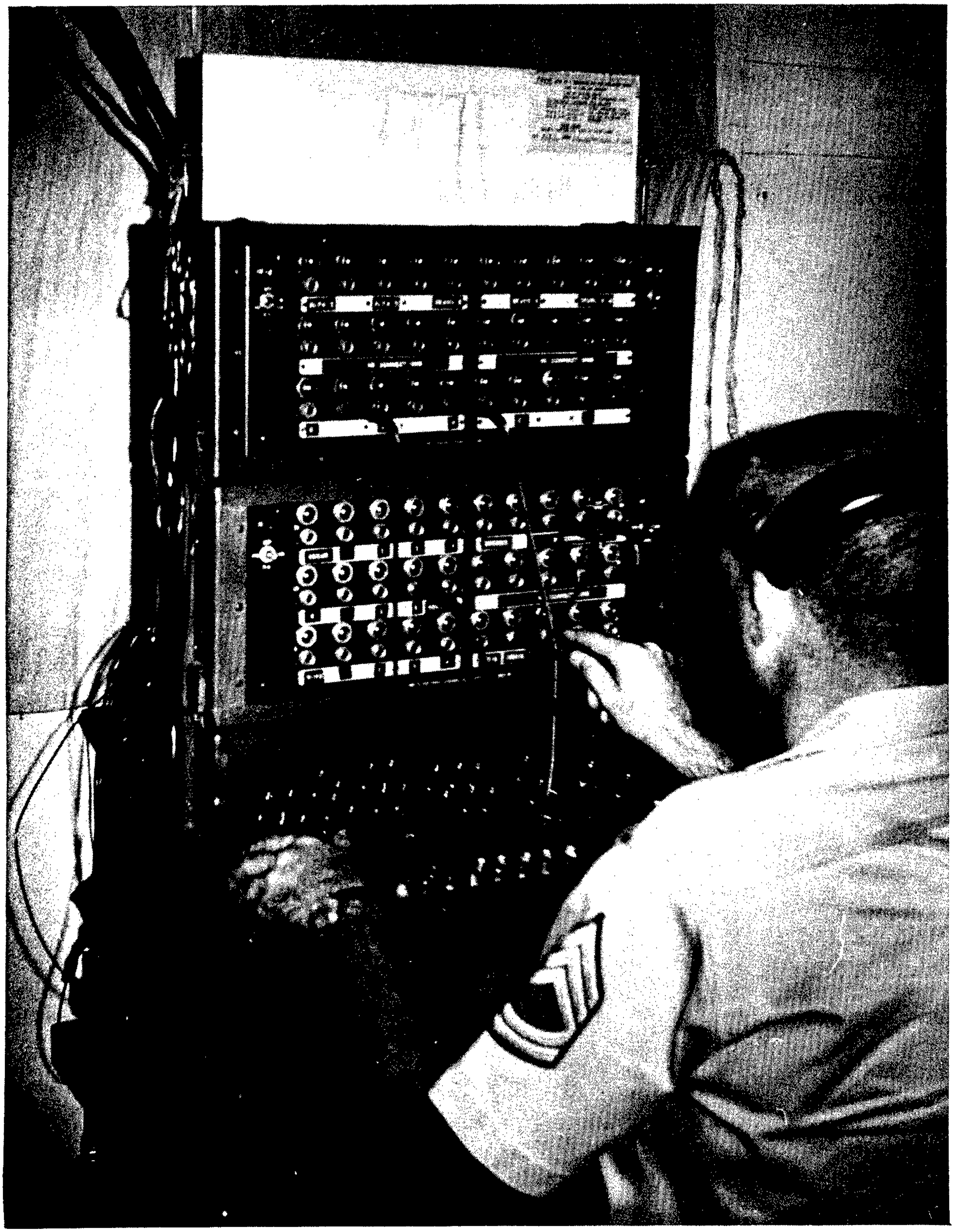

FIG. 4. OPERATOR ANSWERING A SERVICE REQUEST ON A CROWDED BOARD

talking, it is the subscribers' responsibility to ring back the circuit to notify the operator of the freed circuit. Subscribers consistently fail to do this. The operator has a constant need for free circuits to place new calls, so he is forced to do plug supervision regardless of supervisory lamp status.

How this unnecessary time can add up is demonstrated by the fact that at Site 1, where traffic was the heaviest, operators spent an average of seven minutes per hour doing plug supervision, exclusive of disconnects. This problem is largely unjustified and could be greatly minimized through proper subscriber education.

SUMMARY AND CONCLUSIONS

Live switchboard traffic was recorded at three tactical communications sites in South Vietnam. This data was collected to gain information about traffic composition, average total call-processing times, and operator efficiency as a function of call type and traffic conditions.

For purposes of data analysis, service requests were placed into two categories -- normal and information. Calls were further classified as being either local or trunk depending on their immediate termination. This resulted in establishing four basic call types: normal local, normal trunk, information local, and information trunk. Finally, each completed call was divided according to operator function into component elements of search, connect, ring and disconnect, and these elements were studied as influenced by call type and traffic density.

In general, the results of this study were as follows:

1. Traffic Composition -- The bulk of all traffic was normal local calls and they were placed in the normal manner. Information calls, although comprising a small percentage of the total traffic, were predominantly locals -- an indication of poor user habits.

2. Total Average Call-Processing Time -- A best estimate of total average total call-processing time was placed at 20.9 seconds. According to this figure alone, an average operator could extend about three calls per minute. However, the operator has to perform other tasks such as handling aborts and doing plug supervision. Accordingly, a more realistic call-processing capability was placed at 2.5 calls per minute.

3. Operator Efficiency -- Operator efficiency in performing the various call-processing tasks varied both as a function of call type and traffic density. It was determined that call request type (normal versus information) influenced connect times. Information requests, on the average, caused longer connect times, especially for trunk calls. Ring and disconnect times were not affected.

Traffic density affected connect and ring times, each being significantly longer in high traffic. Differences in connect times were attributed to the inherent difficulties of manipulating a crowded board. Reasons for the longer ring times are unclear, which suggest this operator function is highly personalized. Again, disconnect times were not affected.

4. System Efficiency -- Of all service requests 80.1 percent were rung forward; the rest were aborted by reason of busy circuits or system outages. The majority of all aborts resulted from busy trunk circuits.

The information derived from this study supports two general conclusions: (1) to maximize the efficiency of tactical communications systems, circuit requirements must be accurately anticipated and sufficient equipments allocated to fulfill them and (2) optimal performance of even the best planned system can be attained only through proper subscriber education.

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13. ABSTRACT

An initial survey was conducted to identify variables affecting call-processing efficiency in a tactical communications environment from tape recordings of live switchboard traffic obtained at operational sites in South Vietnam.

The collected data were analyzed to furnish specific information regarding traffic composition, average call-processing times, and operator efficiency.

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