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# SURVEY OF METROLINER TELEPHONE USERS AND COMPUTER PROGRAMS FOR ANALYZING TELEPHONE CHANNEL CAPACITY AND LOADING

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FINAL REPORT



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16. Abstract

The results of the survey of the Metroliner telephone users show that 11.5 percent of the passengers used the telephone. Among the users, 71 percent had to wait, 73.5 percent of the passengers recommended telephone service, and 37.2 percent for television. The average telephone demand was estimated. Three computer programs were provided for: (1) space-time diagram of the trains on the track, (2) the number of trains on the track, and (3) the telephone channel-capacity distribution of each train including the loading factor of each channel.

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## PREFACE

The work described in this report was performed by the staff of the Communications Branch of the Electromagnetics Technology Division, Transportation Systems Center. This program on ground-transportation communications is sponsored by the Office of Research, Development, and Demonstrations of the Federal Railroad Administration, Department of Transportation.

The work is divided into two parts. The first part establishes the Metroliner telephone users' behavior and determines the problem areas. The second part is an analysis of the channel capacity of each train, the effects of the train schedule, and the loading factor all of which were transformed into computer programs. The objectives of this work are to improve the present Metroliner telephone services, and to provide data for designing new communication systems for rail transportation.

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# 1. INTRODUCTION

To gain more information on the demands made by passengers on the Metroliner telephone system and the adequacy of the service as well as passenger interest in television on the Metroliner, a questionaire was prepared jointly by FRA, MITRE, and TSC. The survey work was conducted by AMTRAK personnel. The details of this survey and the results are given in section 2.

It was felt by workers at TSC that the direct observation of telephone use would be very helpful. Accordingly, members of TSC-TEC made a trip on one of the Metroliner trains to obtain direct experience. The details and results of this undertaking are given in section 3.

Previously, the average telephone-channel capacity for different telephone-channel distributions and for each individual train was computed by hand. This was very time-consuming. Therefore, a set of computer programs was written to calculate the above quantities for various train schedules, different telephone-channel distributions, and different railways. The programs can be adapted to any standard computer using FORTRAN IV language. The work is given in section 4.

# 2. ANALYSIS DATA FROM SURVEY OF USERS OF METROLINER MOBILE TELEPHONE SYSTEM FROM JULY 17 THROUGH 22, 1972

## 2.1 GENERAL DISCUSSION

To determine the adequacy of the present system, and the demand and response of the telephone users on the Metroliner trains, a survey was conducted between July 17 and 22, 1972. A questionnaire (Table 2.1) was prepared jointly by FRA, MITRE, and TSC. The survey was conducted by AMTRAK personnel. The questionnaire was distributed among the passengers at the beginning of the trip on a Metroliner train running between Washington, D.C., and New York City. The survey was conducted on 14 trains both morning and afternoon, both north and southbound, and on every day of the week. It is believed that the survey covered all circumstances except that of Sunday trains.

Among the 14 trains, the number of responses varies from as many as 117 responses per train to just 1 response. The responses from 11 trains were selected for analysis; of the 3 trains whose data were not included, 2 trains had the very low responses of 1 and 2; and the third train yielded 13 responses but only 1 telephone booth was working. The AMTRAK survey-takers stated that some passengers were quite uncooperative. Table 2.2 shows the date, time of departure, train number, and the number of responses of each train.

Table 2.1 QUESTIONNAIRE FOR METROLINER SURVEY

DATE: ______________________ TRAIN NO.: ____________

1. Where did you get on this train today? (Check one)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | ( ) | Washington | 3 | ( ) | Wilmington | 6 | ( ) | Newark |
| 8 | ( ) | Capital Beltway Sta. | 4 | ( ) | 30 th St., Phila. | 7 | ( ) | New York |
| 2 | ( ) | Baltimore | 9 | ( ) | Metro Park | | | |
| | | | 5 | ( ) | Trenton | | | |

2. Where are you getting off? (Check one)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | ( ) | Washington | 3 | ( ) | Wilmington | 6 | ( ) | Newark |
| 8 | ( ) | Capital Beltway Sta. | 4 | ( ) | 30 th St., Phila. | 7 | ( ) | New York |
| 2 | ( ) | Baltimore | 9 | ( ) | Metro Park | | | |
| | | | 5 | ( ) | Trenton | | | |

3. I did not try to use the phone on the train because (Check one)
   - ( ) a) I had no need
   - ( ) b) I didn't know the phone was there
   - ( ) c) I thought it would be expensive
   - ( ) d) Others

4. I did try to use the phone: How many different parties did you try to call? ________

5. If you tried to use the phone -
   a) Did you have to wait to get in the phone booth?
   ( ) No ( ) Yes; How long ____________

Table 2.1 (Con't)

b) Once in the phone booth, did you have to wait for the light to go off?

( ) No ( ) Yes; How long? ________

c) Did you have to make several tries to make a phone call?

( ) No ( ) Yes; How many times ________

d) At approximately what times did you attempt to make a call?

________ ________ ________ ________

e) At approximately what time did you complete the call?

________

f) The phone call was unsuccessful because:

( ) No free phone booth
( ) Light on all the time
( ) Operator did not answer
( ) The called party was busy
( ) The line was noisy

6. How many times have you used the telephone in the last year on the Metroliner? ________

7. How many trips have you made on the Metroliner in the last year? ________

8. Would you take the Metroliner if there were no telephones on it? ( ) Yes ( ) No

9. Do you believe that telephone service should be provided on all passenger trains? ( ) Yes ( ) No

10. Would you recommend that television be installed on the Metroliner?
( ) Yes ( ) No

11. Would you be willing to pay to watch television on the Metroliner?
( ) Yes ( ) No

REMARKS:

Table 2.2 TRAINS ON WHICH DATA WERE TAKEN

| Date: July 1972 | Time:hours and Day of Departure | Train No. | No. Responses | Users |
|---|---|---|---|---|
| 17 | 0900 (MON) | 106 | 28 | 6 |
| 17 | 1230 (MON) | 113 | 31 | 4 |
| 18 | 1000 (TUE) | 108 | 27 | 4 |
| 20 | 1000 (THU) | 108 | 117 | 6 |
| 20 | 1030 (THU) | 109 | 22 | 1 |
| 20 | 1330 (THU) | 115 | 100 | 10 |
| 20 | 1400 (THU) | 116 | 32 | 6 |
| 20 | 1530 (THU) | 119 | 28 | 1 |
| 21 | 0900 (FRI) | 106 | 23 | 8 |
| 21 | 1230 (FRI) | 113 | 38 | 7 |
| 22 | 0830 (SAT) | 105 | 31 | 2 |

The analysis is concentrated on questions 4 and 5, the answers to which yield the bulk of the information. The data included the average waiting times for the booth and the telephone channel, the distribution of the waiting times, etc.

There were 477 responses and 55 users -- the user responses being 11.5% of the total -- 3 user forms did not have complete information and could not be used in the final analysis. In the process of analysis the following rules were observed:

a. Where the survey data show that the time does not correspond to the train schedule, the data have been discarded.

b. No attempts have been made to distinguish the waiting time for a free channel from the waiting time for an operator to answer.

c. No distinctions have been made as to whether the user is actually waiting outside the booth or is going back and forth between his seat and the telephone booth. (In any future survey, the question should be made more explicit.)

d. When there is an incomplete answer, no attempt has been made to complete the answer.

The final analysis of the data is based on 52 user forms. Again in any further survey, the questions should be revised to be more precise and unambiguous.

## 2.2 EXTENT OF WAITING TO USE THE TELEPHONE

The following table gives the number and percentage of user respondents that (a) did not have to wait at all to use the telephone, (b) had to wait outside the booth only, (c) had to wait in the booth for a free channel only, and (d) waited both for the booth and a free channel.

Table 2.3 EXTENT OF WAITING TO USE TELEPHONE

| | (a) No Waiting At All | (b) Waiting for Booth Only | (c) Waiting for Free Channel Only | (d) Waiting Both for Booth and Free Channel |
|---|---|---|---|---|
| Users (No.) | 15 | 9 | 15 | 13 |
| Users (Percent) | 29 | 17 | 29 | 25 |

Thus, 29 percent did not have to wait at all, while 71 percent had to wait in one way or another.

### 2.2.1 Extent of Waiting to Get into Telephone Booth

From the group of respondents who waited to get into the telephone booth, we obtained the results shown in the following table. Four respondents, however, answered "yes" (they waited), but did not give the length of time in minutes.

Table 2.4 TIME SPENT WAITING TO GET INTO TELEPHONE BOOTH AND CORRESPONDING NUMBER OF RESPONDENTS

| Time (Minutes) | 0 | 1 | 4 | 5 | 6 | 5-10 | 5-12 | 10 | 15 | 20 | "Yes" |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Respondents (No.) | 30 | 1 | 1 | 5 | 1 | 1 | 1 | 2 | 5 | 1 | 4 |

Figure 2.1a shows a plot of the results: 57.7 percent of the users did not have to wait to get into a booth, while 42.3 percent had to wait to some extent. Figure 2.1b shows the percentage of respondents who had to wait "T" minutes or more (only those who gave a numerical answer are taken into account in this figure): 33 percent had to wait 5 minutes or more, and 17 percent had to wait 10 minutes or more. From these respondents, the mean waiting time is computed to be 3.48 minutes.

2.2.2 Extent of Waiting inside of Telephone Booth for Free Channel

When a caller enters a booth and lifts the telephone receiver, a light on the panel will go on if all channels are occupied. Question 5 (b) asks, "Once in the phone booth did you have to wait for the light to go off? If yes, how long?" Of the respondents who replied, "yes" to this question, a number did not give numerical answers as to the length of time: 4 answered only "yes," 1 answered "very long," 1 answered "indefinitely." The distribution of waiting time for those who gave numerical answers are shown in the following table:

Table 2.5 TIME SPENT WAITING FOR FREE CHANNEL AND CORRESPONDING NUMBER OF RESPONDENTS

| Time (Minutes) | 0 | 1 | 2 | 2-3 | 5 | 5-10 | 10 | 10-15 | 15 | 60 | (Waited) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Respondents (No.) | 24 | 2 | 2 | 1 | 4 | 2 | 6 | 2 | 2 | 1 | 6 |

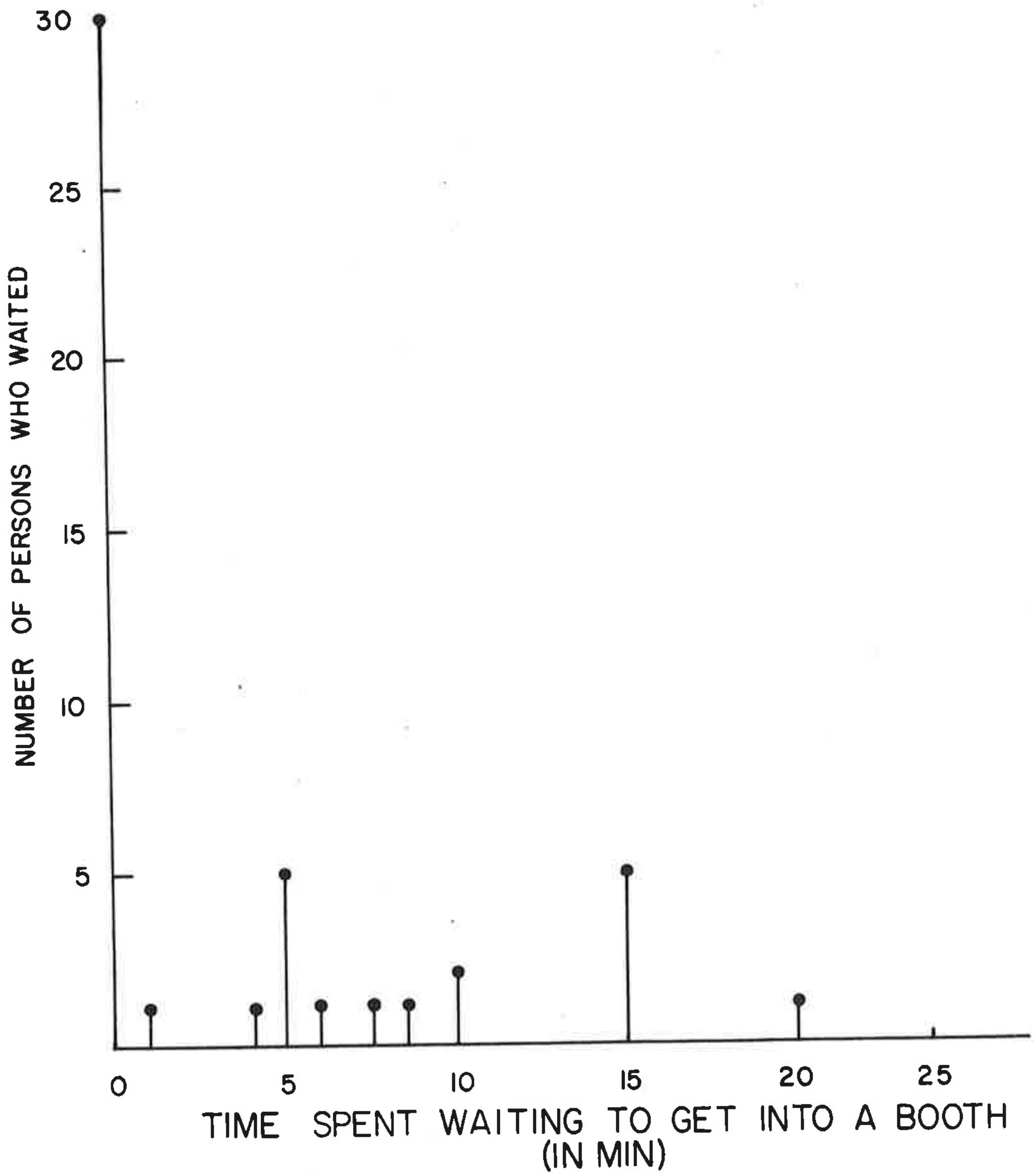



Figure 2.1a Time Spent Waiting to get into Telephone Booth and Corresponding Number of Respondents Who Waited

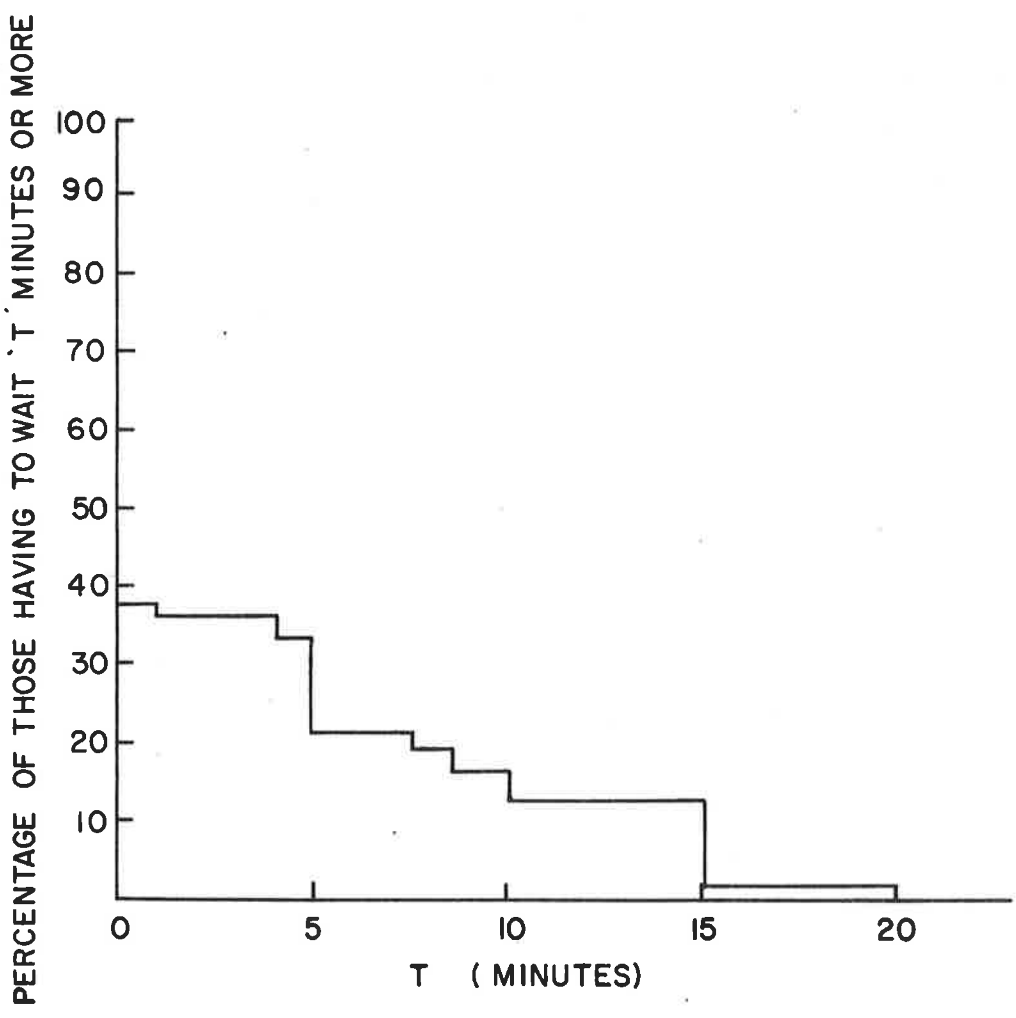



Figure 2.1b Percentage of Respondents Who Had to Wait "T" Minutes or More to Get into Booth

Figure 2.2a shows this distribution in graphic form: 46 percent of the users did not have to wait once they were in the booth, while 54 percent had to wait to some extent.

Based on those "numerical" respondents (who gave numerical answers to the length of time they waited), the percentage of those who waited for more than "T" minutes is given in Figure 2.2b, i.e., 37 percent had to wait 5 minutes or more, while 24 percent had to wait 10 minutes or more. From the numerical answers, we obtained a mean waiting time of 4.7 minutes. If we leave out the respondent who claims that he waited for 60 minutes, the mean waiting time would be 3.5 minutes.

### 2.2.3 Total Extent of Waiting Time

We have also analyzed a total waiting time for the respondents; that is, the sum of waiting for the booth and for a free channel. The results for the "numerical" respondents are shown in Figure 2.3a. Also, for the numerical respondents, the number of users who had to wait "T" minutes or more of total waiting time is given in Figure 2.3b, i.e., 56 percent had to wait 5 minutes or more, and 39 percent had to wait 10 minutes or more. The mean waiting time of the numerical respondents was 8.05 minutes. If we discount the respondent who claimed that he waited for 60 minutes, the mean waiting time would be 6.9 minutes. Delays in the booth may also be caused by the operator who services the caller. This factor was not included in the questionnaire. It may be that callers who waited for the operator included this time in their estimate of how long it took for the lights to go off.

## 2.3 DISTRIBUTION OF CALL ATTEMPTS

### 2.3.1 Distribution of Number of Attempts to Call Party

From the data it is found that most of the callers called one party. The following table gives the distribution of attempts to obtain a connection for the one-party callers.

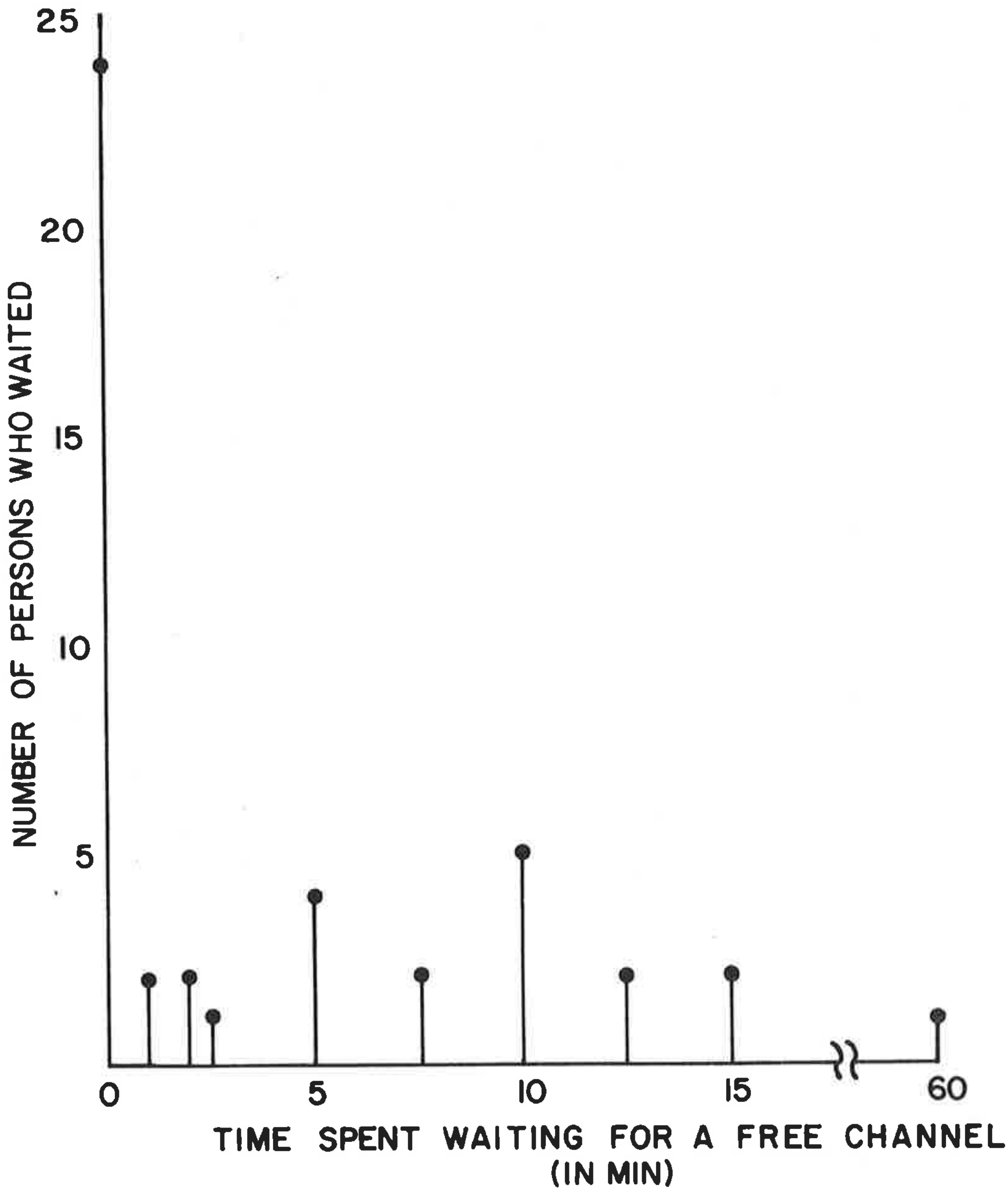



Figure 2.2a Time Spent Waiting for Free Channel and Corresponding Number of Respondents

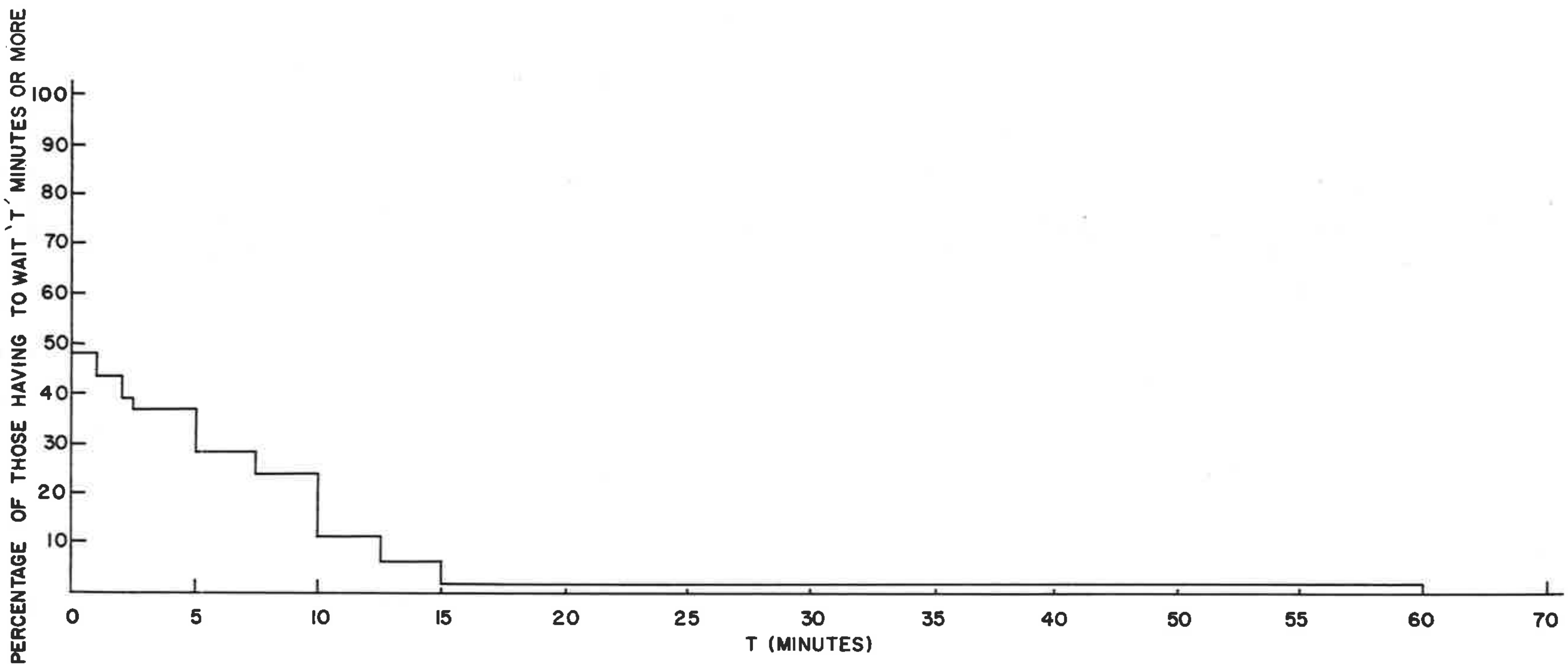



Figure 2.2b Percentage of Respondents Who Had to Wait "T" Minutes or More for Free Channel

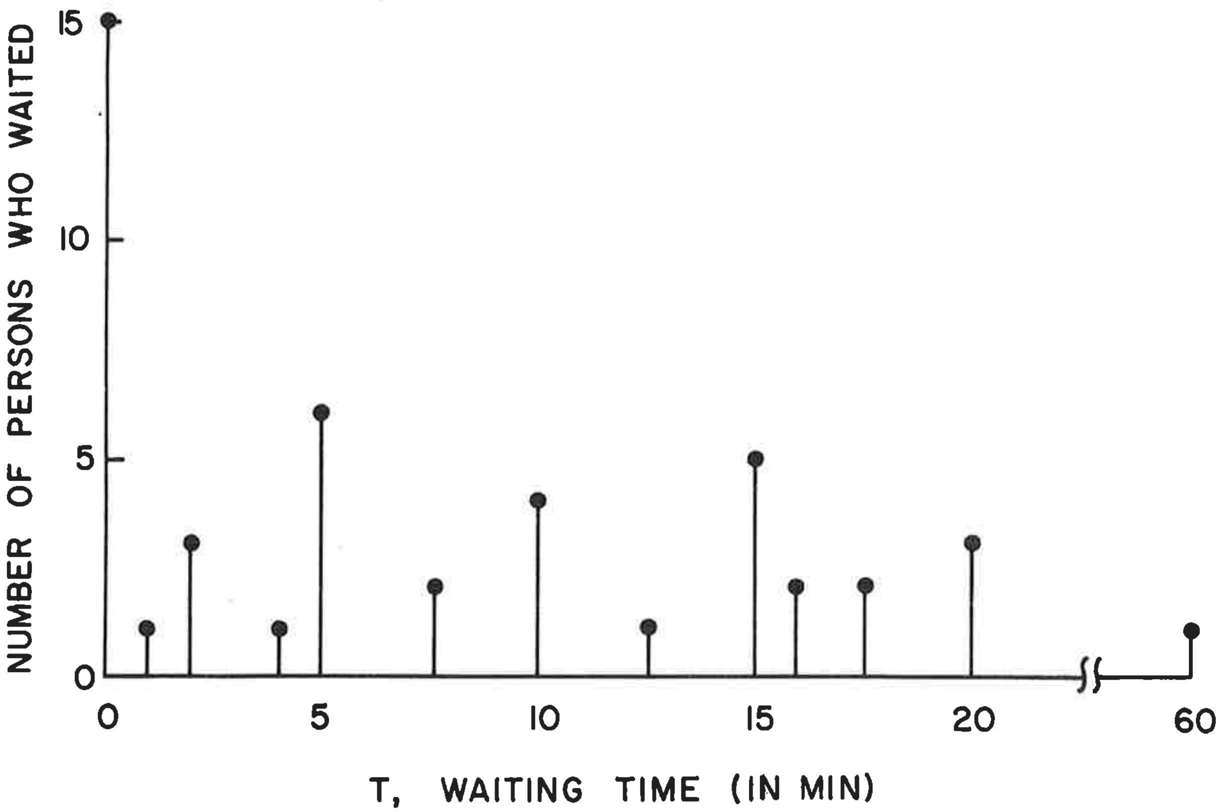



Figure 2.3a Total Waiting Time for Booth and Free Channel and Corresponding Number of Respondents

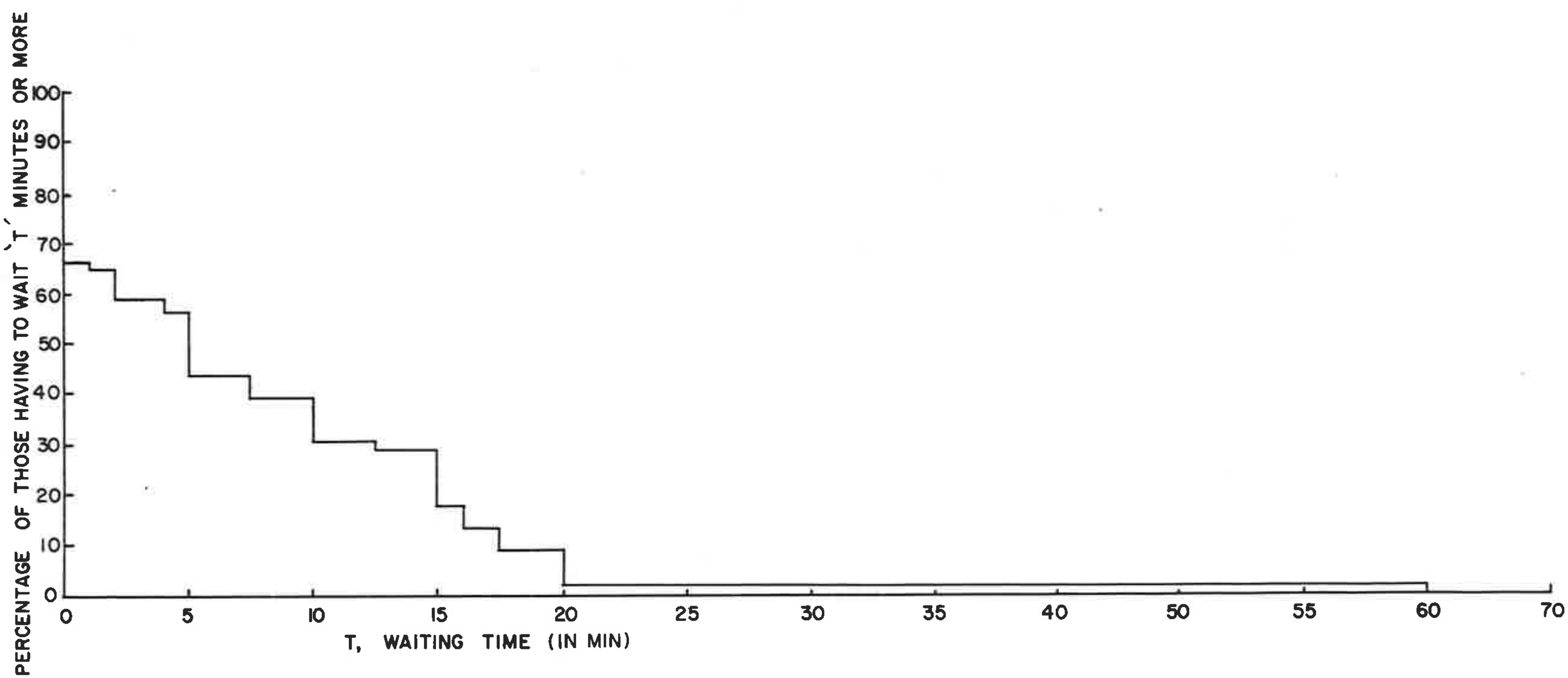



Figure 2.3b Percentage of Respondents Who Had to Wait "T" Minutes or More (Sum of Waiting Time to Get into Booth and Waiting Time for Free Channel)

Table 2.6 NUMBER OF PERSONS WHO MADE GIVEN NUMBER OF ATTEMPTS (ONE-PARTY CALLERS)

| No. Tries | 1 | 2 | 2-3 | 3 | 4 | 5 | 7 | 9 | 20 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| No. Persons | 17 | 9 | 1 | 5 | 5 | 1 | 1 | 1 | 1 | 1 |

We shall consider two types of attempts: specific attempts at a given time and a prolonged endeavor to reach a party (which may require a number of attempts). The former we will refer to as a "specific attempt," and the latter as a "prolonged endeavor." The attempts shown on Table 2.6 are then specific attempts as given by the respondents.

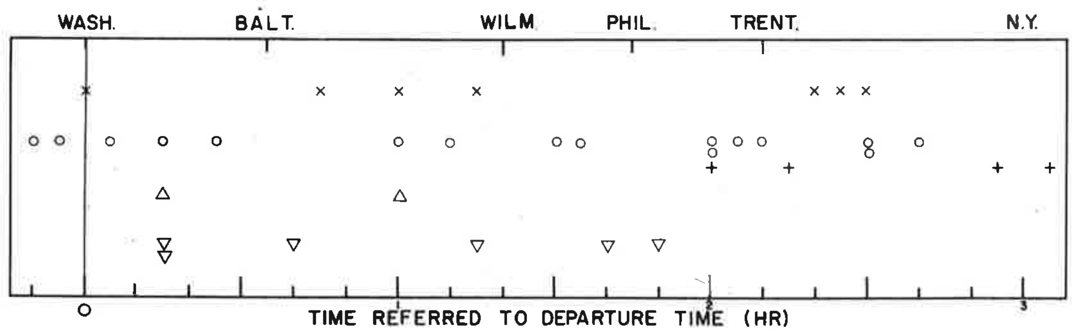
### 2.3.2 Distribution of Attempts Made to Use Telephone versus Time

The train trip between New York City and Washington, D.C. takes approximately 3 hours. In Figure 2.4a and 2.4b, we have made rough plots of the distribution of specific attempts relative to the train-departure time. The times the trains would arrive at some of the main stations in the journey are also given approximately. The small sample of the present survey is insufficient to yield a good statistical distribution of attempts. For train No. 115, there is a noticeable absence of calls during the earlier part of the trip, and a concentration of attempts as the train approaches the end of the trip between Baltimore and Washington.

## 2.4 DISTRIBUTION OF UNSUCCESSFUL TELEPHONE CALLS

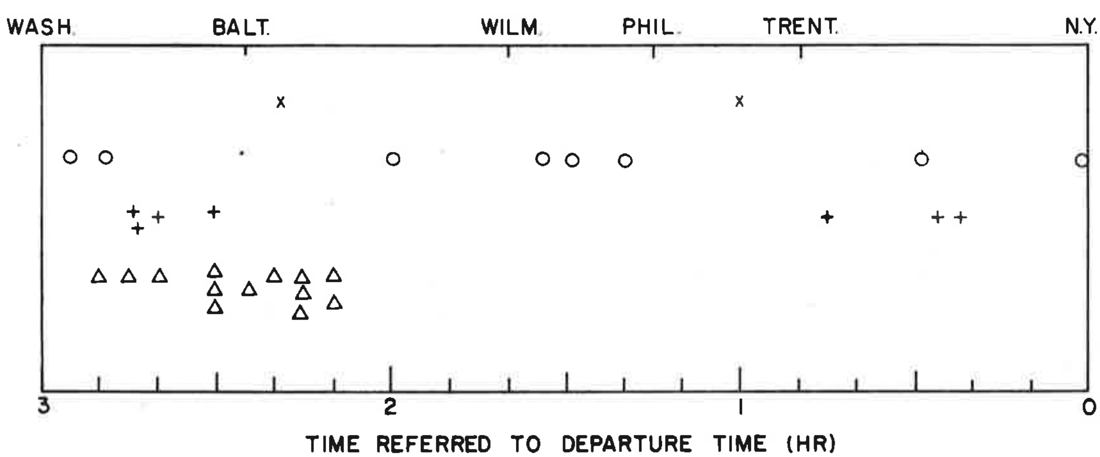
From the survey data, it is estimated that about 44 percent of the prolonged call endeavors are not successful.

Among the unsuccessful specific-call attempts, about 9 percent are due to the absence of a free booth, another 32 percent are that the light is on all the time, some 18 percent are the operator not answering, and about 18 percent are that




| | TRAIN | DEPARTS | | |
|---|---|---|---|---|
| × | 106 | 0900 | 7/17/72 | MON |
| ○ | 106 | 0900 | 7/21/72 | FRI |
| + | 108 | 1000 | 7/18/72 | TUE |
| △ | 108 | 1000 | 7/20/72 | THU |
| ▽ | 116 | 1400 | 7/20/72 | THU |

Figure 2.4a Distribution of Attempts Made to Use Telephone in Some Northbound Trains




| | TRAIN | DEPARTURE | | |
|---|---|---|---|---|
| X | 105 | 0830 | 7/22/72 | SAT |
| O | 113 | 1230 | 7/21/72 | FRI |
| + | 113 | 1230 | 7/17/72 | MON |
| △ | 115 | 1330 | 7/20/72 | THU |

Figure 2.4b Distribution of Attempts Made to Use Telephone in Some Southbound Trains

the line is noisy. Therefore, absence of a free channel is a major factor for the lack of success on call attempts. Other reasons include being cut off, and absence of a dial tone.

## 2.5 SOME COMPARISON OF PRESENT SURVEY AND AMERICAN TELEPHONE AND TELEGRAPH (AT&T) SURVEY

The results obtained in this survey of a relatively small sample can be compared with AT&T survey made in July 1970 where the telephone-user sample was about 6 times larger than our own (Reference 1).

a. Waited to get a free booth: AT&T 25 percent, this survey 42 percent.
b. Waited to get a free channel: AT&T 65 percent, this survey 54 percent.
c. Unsuccessful call attempts: AT&T (which did not explain whether they were specific attempts or prolonged endeavors) 35 percent, this survey 44 percent for prolonged endeavors, and 66 percent for specific attempts.
d. Unsuccessful call attempts because "all channels were busy": AT&T 52 percent, our survey 32 percent for specific attempts.

## 2.6 RESPONSES ON ADDITIONAL QUESTIONS

Reduction of the data on some of the questions posed by the FRA gave the following:

a. "Would you take the Metroliner if there were no telephone on it?" Yes, 94.3 percent; No, 1.1 percent; No answer, 4.6 percent.
b. "Do you believe that telephone service should be provided on all passenger trains?" Yes, 73.5 percent; No, 17.4 percent; No answer, 9.1 percent.
c. "Would you recommend that television be installed on the Metroliner?" Yes, 37.2 percent; No, 56.8 percent; No answer, 6.0 percent.

d. "Would you be willing to pay to watch television on the Metroliner?" Yes, 19.3 percent; No, 74.8 percent; No answer, 5.9 percent.

Possibly the third question could be modified to "Would you recommend that television be installed on certain cars of the Metroliner?" As it is, although a majority of the respondents favored telephone service on all passenger trains, only about one-third favored the installation of television and only one-fifth of the respondents would pay for it. Thus, a TV car would satisfy the desire of this group without interfering with the other passengers.

## 2.7 SUMMARY OF SOME MAIN POINTS OF SURVEY

The survey was conducted between 0830 and 1530 hours on every day except Sunday and Wednesday. From a group of 477 respondents, it was found that 11.5 percent of the respondents tried to use the telephone system. Of the user group, 71 percent had to wait to use the telephone. Approximately 42 percent had to wait to some extent to get into a booth; 33 percent had to wait 5 minutes or more; and the mean waiting time was 3.48 minutes for those who gave numerical values for the waiting time. Of the users, 54 percent had to wait for a free channel after getting into the booth; 37 percent had to wait 5 minutes or more; while 24 percent had to wait 10 minutes or more; the mean waiting time was 4.7 minutes. In considering the total waiting time, sum of waiting at the booth and for a free channel, we found that 56.5 percent had to wait 5 minutes or more, and 39 percent had to wait 10 minutes or more; the mean waiting time of those who gave numerical values was 8.05 minutes. Delays in the booth may also be caused by waiting for the operator to service the call.

The great majority of users called one party only. Of these, 36 percent had to make 3 attempts or more. We distinguish specific-call attempts from prolonged-call endeavors to reach a party. It is estimated that 44 percent of the prolonged call endeavors are not successful. About 32 percent of the unsuccessful specific-call attempts are that the light is on all the time, and about 18 percent are that the operator is not answering.

Analysis of some of the questions posed by the FRA group gave the following results:

The respondents would take the Metroliner even if there were no telephone service on it; but 73.5 percent of the respondents believe that such telephone service should be provided on all passenger trains; 37.2 percent of the respondents favor installation of television, while 56.8 percent are opposed; 19.3 percent would pay to watch television, so that the best compromise of conflicting interest would be to install television only in certain cars.

After analyzing the response data, we have become more aware of certain problems in terminology. This will lead to better phrasing in any future questionnaires.

# 3. DIRECT OBSERVATION OF TELEPHONE USE ON METROLINER TRAIN

## 3.1 GENERAL DISCUSSION

From the beginning of the Metroliner survey program, it was apparent that a trip on the Metroliner train to observe telephone-use first-hand would be desirable. The results obtained from the questionnaire as reported in the previous section reinforced this view. Accordingly, on September 30, 1972, two members of the Electromagnetic Technology Division's Communications Branch of the Transportation Systems Center rode train No. 112. The particular train left Washington at 1200 hours and arrived in New York City at about 1500 hours. On the day of the observation, the train consisted of two Metroclub cars, each with a telephone, two Metro Snack Bar Coaches, each with a telephone, and two Metroliner coaches.

The telephone booth in each Metroclub car was located at one end of the car. The booth had a sliding glass-door opening on the aisle, but the other three walls of the booth were opaque. A washroom was located across the aisle from the booth, so that sometimes it was not possible to distinguish between passengers who were waiting for the washroom from those who were waiting for the telephone booth until they entered the one or the other. From the swivel seat across the aisle from the telephone booth, one would look into the booth through the open doorway or through the closed glass door. Figure 3.1 shows the booth and the general area. Figure 3.2 shows the telephone instrument panel. Provided that the telephone user did not stand in an unusual way and block the view, one was able to see the user dial the number (or the operator). From the chair one would also see whether the light, which indicated that all channels were busy, was on or off. When all channels were occupied, the lighted box read, "All channels are busy, please hang up."

The telephone booth in the Metro Snack Bar Coach was located in the middle of the car opposite the snack bar (see Figure 3.3). The passenger coach seats faced one way on some cars, and the opposite way on other cars. An observer from the nearest coach seat across the aisle from the telephone booth could look directly into the booth, provided that the seat happened to be facing toward the booth. If the seat were facing the other way, observation was not at all convenient.

The order of the cars for train No. 112 was as follows: Club car, snack coach, coach, coach, snack coach, and club car. Telephone booths were located on the club cars and snack coaches only. The club car had 34 seats, the snack coach had 69 seats, while the coach had 76 seats. One would expect (if all telephones were functioning properly) heavier use of the telephones on the snack coaches because of the proximity of a larger number of passengers to these telephones.

### 3.2 EXISTENCE OF A MAINTENANCE PROBLEM ON OBSERVED TRAIN

It became apparent on this trip that a maintenance problem existed. According to the intended design of the Metroliner telephone, a user should get one of two responses: (1) a dial tone, indicating that he could proceed with dialing, (2) a light which came on to signify that all channels were busy. If neither of these events occurred, the telephone was malfunctioning.

Of the four telephones on board train No. 112, three were out of order. When the receiver was lifted on these three, sometimes the channel busy light came on (a valid response), and at other times neither a dial tone nor a channel busy light came on (not a valid response). At no time, however, could calls be made on any of these phones. It must be pointed out here that whether or not the telephones were malfunctioning could not be determined from the fact that a busy light came on. Only when subsequent trials gave the invalid response could one determine that these telephones were not working

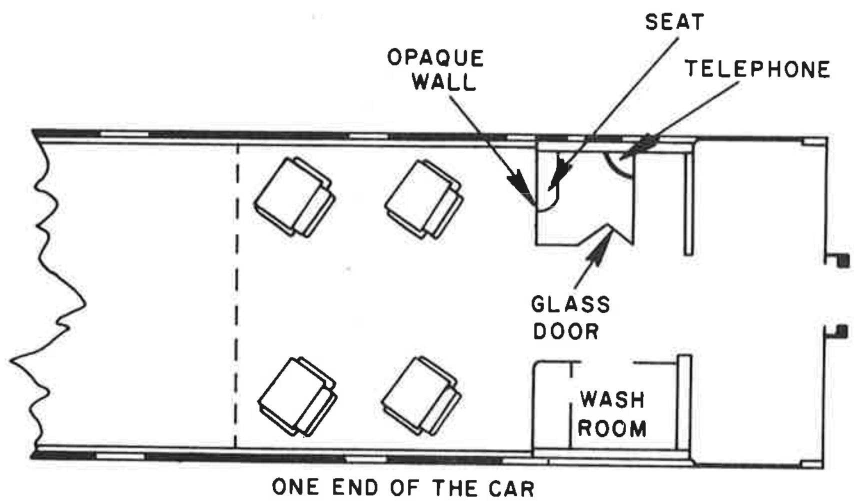



Figure 3.1 Diagram Showing Telephone Booth and Vicinity in Metroclub Car

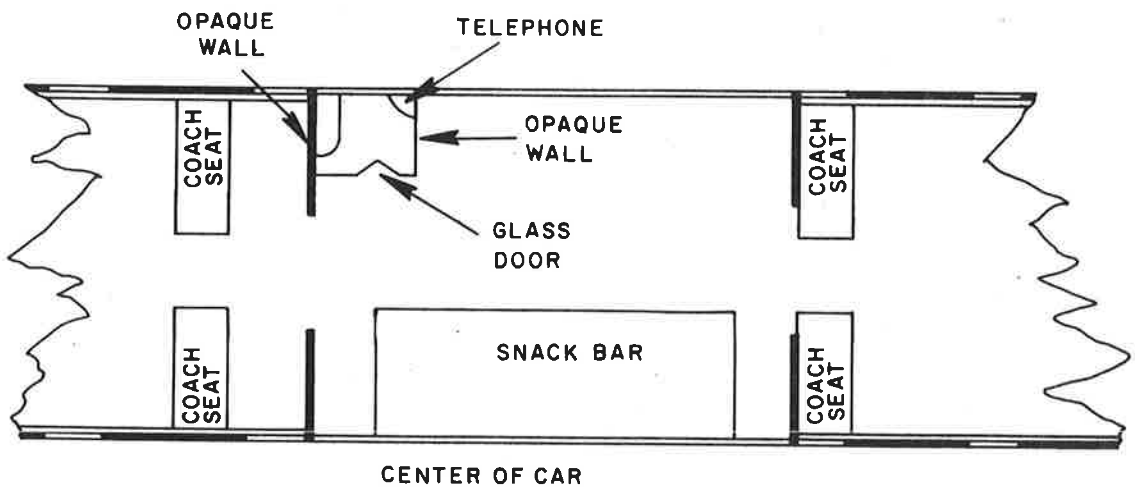



Figure 3.3 Diagram Showing Telephone Booth and Vicinity in Metro Snack Bar Coach

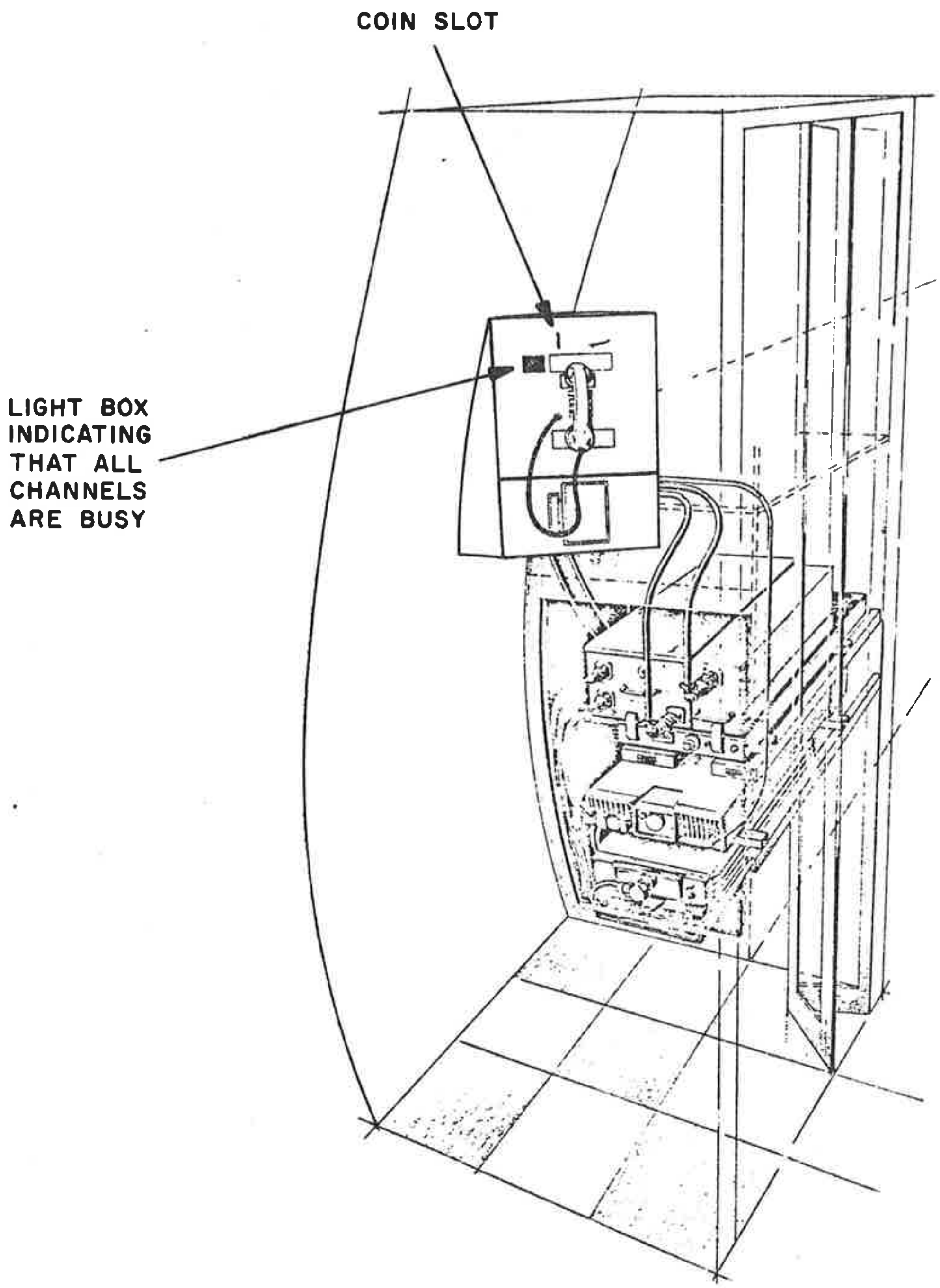



Figure 3.2 Telephone Instrument Panel in Metroliner Trains

properly. The fact that most of the telephones were malfunctioning on this train might have been a chance occurrence and one should not conclude that this was so on all trains.

It was learned on this train trip that a regular telephone maintenance program did not exist. Malfunctions when discovered would be reported by the personnel on board the train, who could find it difficult to carry out this task. To remedy this apparent maintenance problem, it is recommended that:

a. A regular and frequent maintenance program be initiated.
b. Personnel on board be instructed on how to recognize a telephone which is out of order and to report such telephones immediately.

A simple check can be made by lifting the telephone receiver. According to the response, the following conclusions can be drawn:

1) Dial tone - the telephone appears to be functioning properly.
2) Channel's busy light - whether or not the telephone is malfunctioning cannot be determined from the response. The phone should be checked on later occasions until (1) or (3) occurs.
3) Neither dial tone nor channel's busy light - the telephone is malfunctioning and should be reported.

Since passengers are not familiar with these distinctions, it is not adequate to rely on them to detect malfunctions. While a completely new Metroliner telephone system is desirable, it is felt that considerable improvement in telephone service can be achieved through proper maintenance of the present system.

### 3.3 USE OF TELEPHONE ON METROCLUB CAR

Since only the telephone on the Metroclub car was working properly, most of the observations were made on this telephone.

Eleven persons used this telephone. The booth was occupied for a total of about 110 minutes or about 60 percent of the time during the entire train trip (see Figure 3.4). Many of the passengers came from other parts of the train to use this telephone, which was the only one working. We have estimated the demand made on this telephone by noting the conversation time of the successful users, and also, by allotting the average conversation demand time of 4 minutes to the unsuccessful users who attempted to obtain a connection. We further assume that they did not return to try again. The estimate is rough since one is not able always to determine exactly when the conversation began in the booth. We have then 82 minutes of demand or about 0.44 erlang for the train. This is low compared to the 0.7 erlang per train which was computed from the figures given by AT&T (Mr. E. Price of AT&T gave 3.5 erlang per 1000 passenger hours, with about 200 passengers in a train on the average, in Reference 2, p. 32). This demand, however, is obtained from the successful calls only, so that when the unsuccessful calls are also taken into account, the AT&T demand is estimated to be 1.1 erlangs per train. The observed demand for train No. 112 is lower bound since presumably, if the other three telephones were functioning properly the observed demand on the four telephones would exceed that recorded on the one that was working properly.

## 3.4 OBSERVATIONS OF BEHAVIOR OF TELEPHONE USERS

Mathematical models of phone use assume idealized behavior of users, relying on concepts such as waiting time (waiting model) or call attempts (Erlang model). It might be anticipated that these idealized concepts describe actual behavior patterns only in an approximate and somewhat ambiguous manner. Observations during the trip have confirmed this.

A passenger who is waiting for a channel to become available, or for the telephone booth to become available, will in some cases clearly indicate this by sitting in the phone booth or waiting outside. In other cases, however, a potential

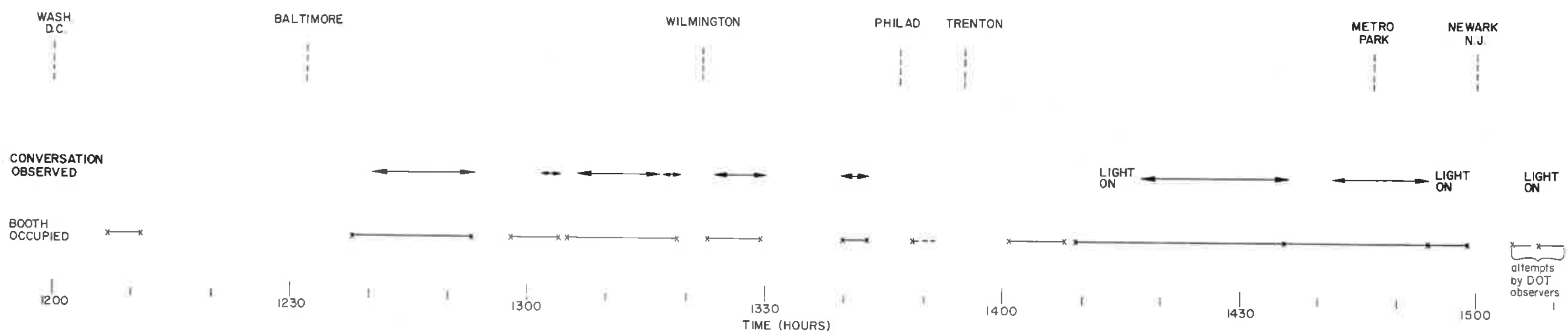
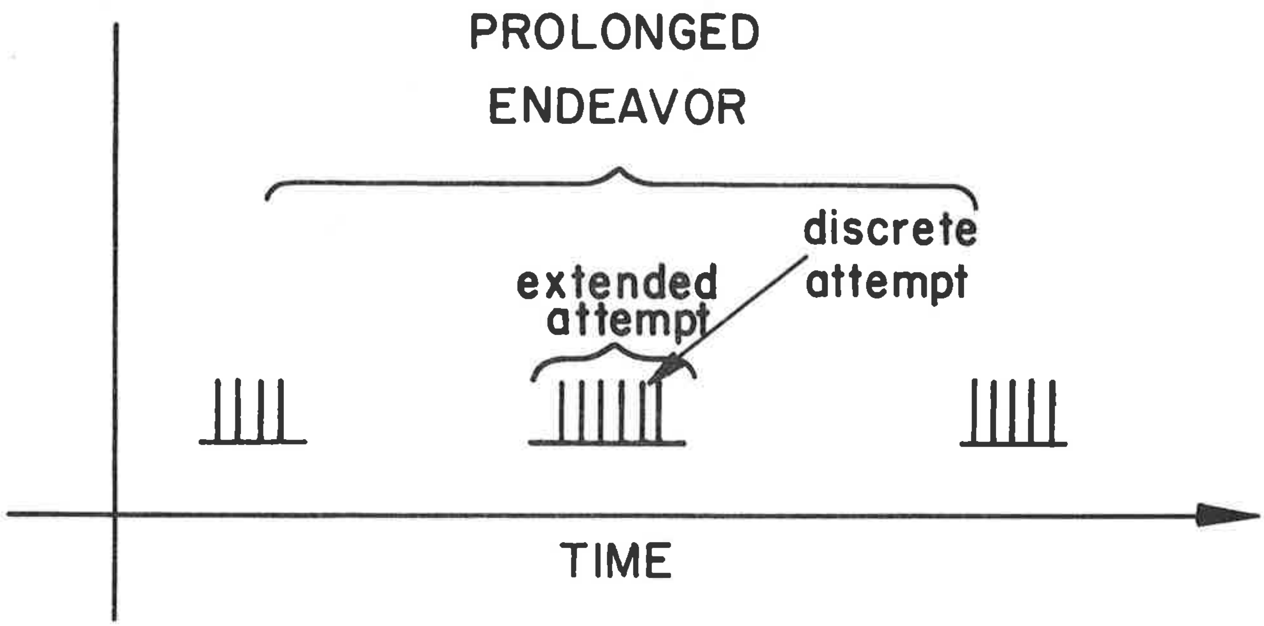



Figure 3.4 Observations on Telephone Use on Metroclub




Underline indicates time during which user occup
booth (extended attempt). Vertical lines indicate
time at which receiver is lifted (discrete attemp
Totality of this effort is prolonged endeavor.

Figure 3.5 Possible Behavior Pattern of Telephone User

user may not be so assertive, i.e., he may keep an eye on the telephone from his seat or get up to check the telephone only occasionally.

The concept of an attempt to make a call is also ambiguous and should be further categorized. Typically, a passenger who wishes to make a call will enter the phone booth and lift the receiver. If he fails to obtain a channel, he may wait anywhere from a few seconds to a minute and then lift the receiver again. Each of such actions will be called a "discrete attempt." The passenger may remain in the booth for a period ranging from a minute or two to a sizeable fraction of an hour while he repeats such discrete attempts. The period that he remains in the booth will be called an "extended attempt." If he continues to be unsuccessful, he may leave the booth, and then, return sometime later to try to place the call. Altogether these efforts will be called a "prolonged endeavor." Figure 3.5 indicates how the efforts of an individual passenger may be placed in time.

## 3.5 SUMMARIZING REMARKS

Direct observation of telephone use was very instructive. We found that for a number of telephones there was neither a dial tone nor a busy channel light and that a maintenance problem existed. The mode of observation we used enabled us to determine the occupation times for the monitored booth but not precisely the time when a connection was made. Data on waiting times would require means as given in section 2. The observed demand for the one phone that was working is consistent with estimates from the data obtained from AT&T. Observations of attempts to use the telephone show that one may distinguish three different types of "attempts." In preparing future questionnaires, one should take these categories into account.

# 4. COMPUTER PROGRAM FOR METROLINER TELEPHONE CHANNEL CAPACITY AND MODELING

## 4.1 GENERAL DISCUSSION

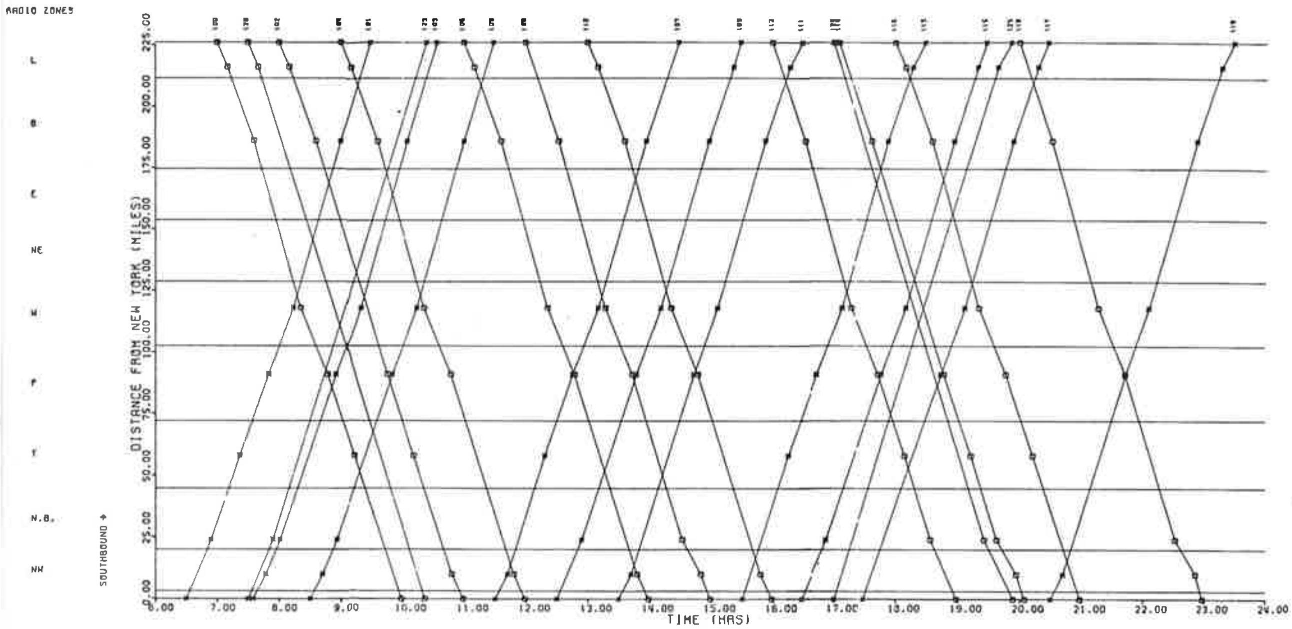
In Reference 2, the average telephone-channel capacity was calculated for three different telephone-channel distributions. In addition, the telephone-channel capacity distribution of each individual train was computed. The above computations were all done by hand which made the calculations very slow, tedious, and inefficient. Therefore, a set of computer programs was written to calculate the above quantities for various train schedules, different telephone-channel distributions, and various railways. The programs are designed in such a way that they can be adapted to any standard computer, using FORTRAN IV language. It is expected that they will make it easier to compute the efficiency of particular telephone-channel distributions, the effects of train-scheduling, and the average distribution of telephone channels per train. The programs will be discussed, and some results obtained with th November 1971 and April 1972 schedules will be demonstrated.

## 4.2 PROGRAMS

There are four separate programs, each with its own functions. They are named as follows: Rail Program, Track Program, Telex 1, and Telex 2. The inputs, outputs, and general function of each program will be discribed in the following. For detail program inputs, formats, functions, flow charts and listings, and others, see the four volumes of reference 3.

### 4.2.1 Rail Program

The basic function of the rail program is to provide a computer plot of the space-time trajectory of each train for a given train schedule, station-spacing, and telephone radio-zone distribution. The aim of the plot is to give the planner an overall view of the trains on the track. Figures 4.1 and



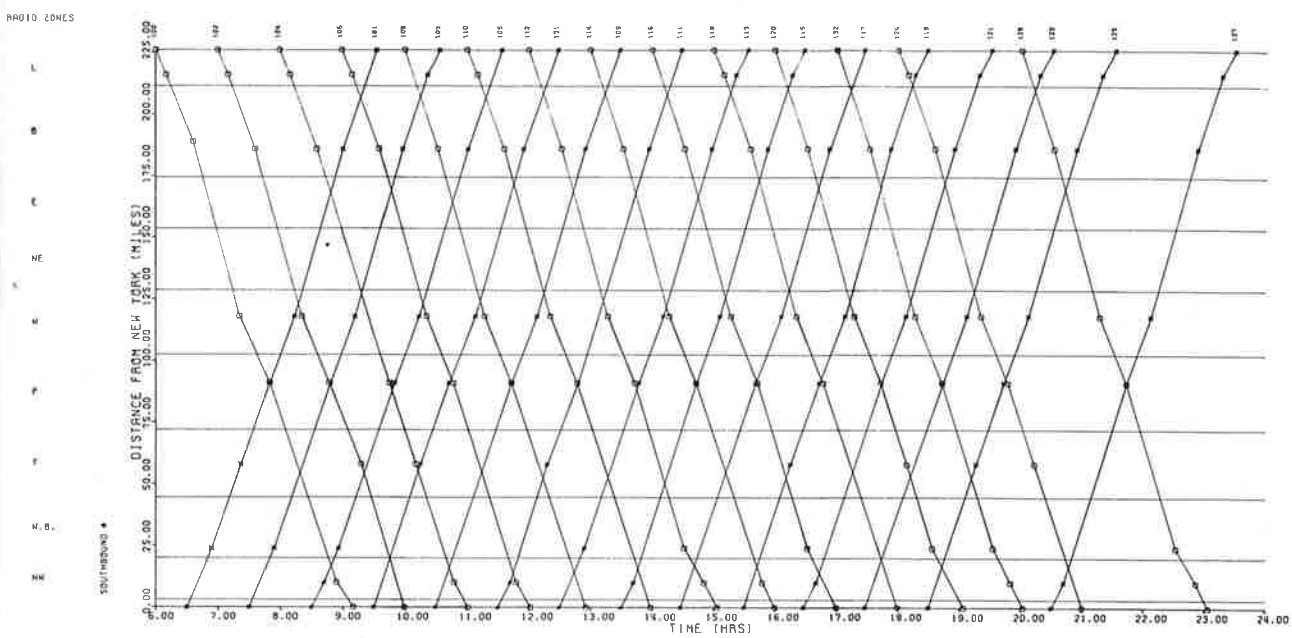




Figure 4.1 (top) Space-Time Plot Showing Trajectories of Metroliner Trains -- November 1971 Schedule

Figure 4.2 (bottom) Space-Time Plot Showing Trajectories of Metroliner Trains -- April 1972 Schedule

4.2 show the space-time trajectory plots for the Novermber 1971 and April 1972 schedules, respectively. With a quick look, one would notice that the November 1971 schedule leads to a crowded situation for the morning and afternoon trains in the Philadelphia area. In addition the average speed of each train between station stops is calculated, which is indicative of the speed variation on the track. Figure 4.3 shows the average speed of Metroliner train 113 between stations versus the distance from New York City. We note that the average speed between Wilmington, Delaware and Baltimore, Maryland is around 90 mph while on other stretches of the track there are much lower speeds. No attempt has been made to determine a speed profile. Obviously, the top speed would be much higher than the average speed. Whenever there is one time given at a station stop, this time is used for calculating the speed on both sides of the track. The input data of the program consist of:

a. Number of trains and number of radio zones,
b. Names of the radio zones,
c. Train numbers,
d. Distances for the boundaries of each radio zone, taking New York as the origin,
e. Number of stops made by each train including departure and arrival stops, and
f. Train schedule: The number of stops of each train, arriving and departing time at each stop, and the distance of each stop measured from New York.

4.2.2 Track Program

This program tabulates the number of trains on the entire track versus time. The results of the computations are shown in Figures 4.4a and 4.4b for the November 1971 and April 1972 schedules, respectively. One may notice that the track is more congested at certain times, and there is wider variation for the November 1971 schedule during morning and afternoon hours, whereas the April 1972 schedule provides a more uniform distribution of the number of trains on the track. The inputs are:

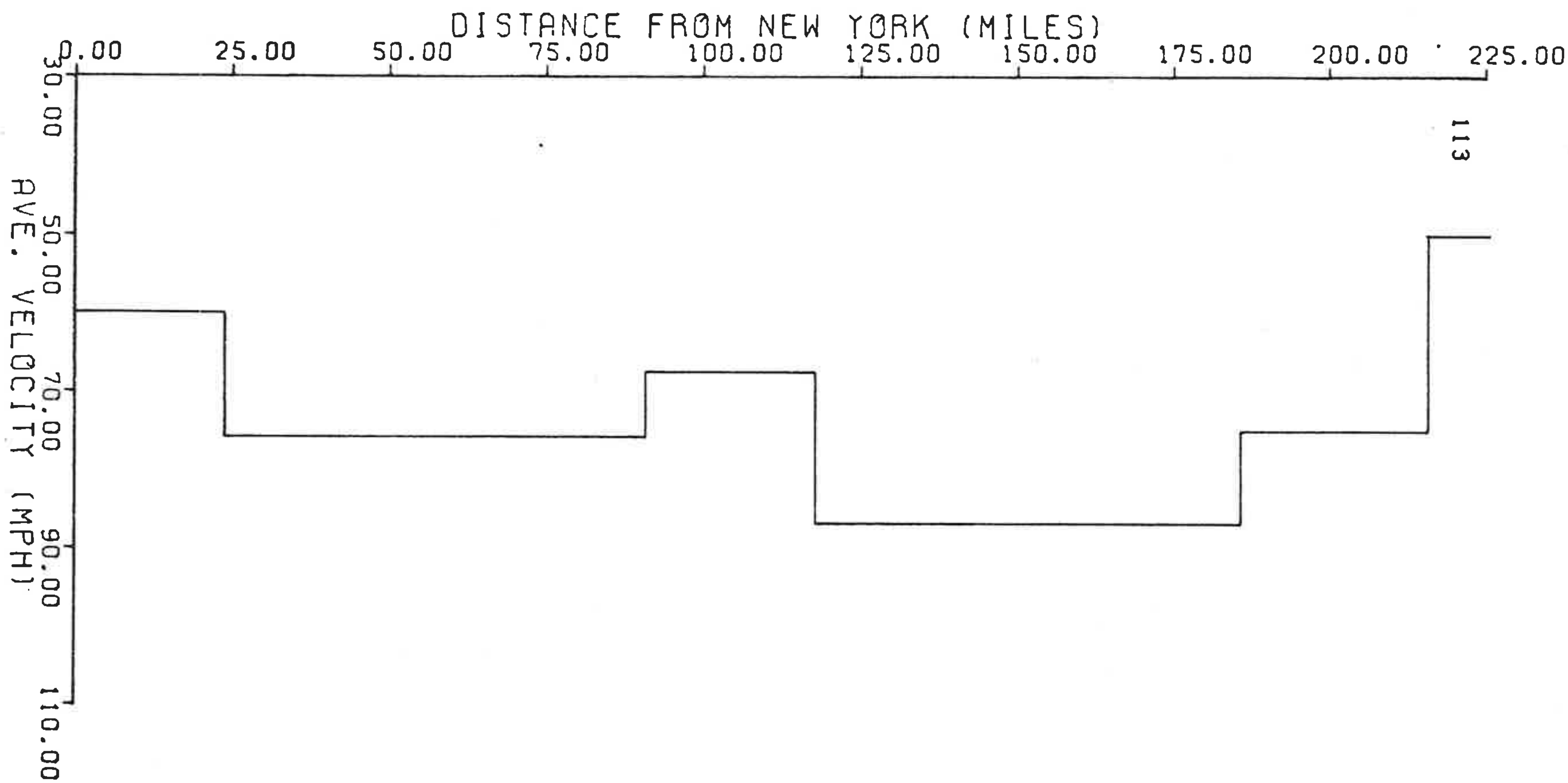



Figure 4.3 Average Speed of Metroliner Train 113 between Stations Versus Distance from New York

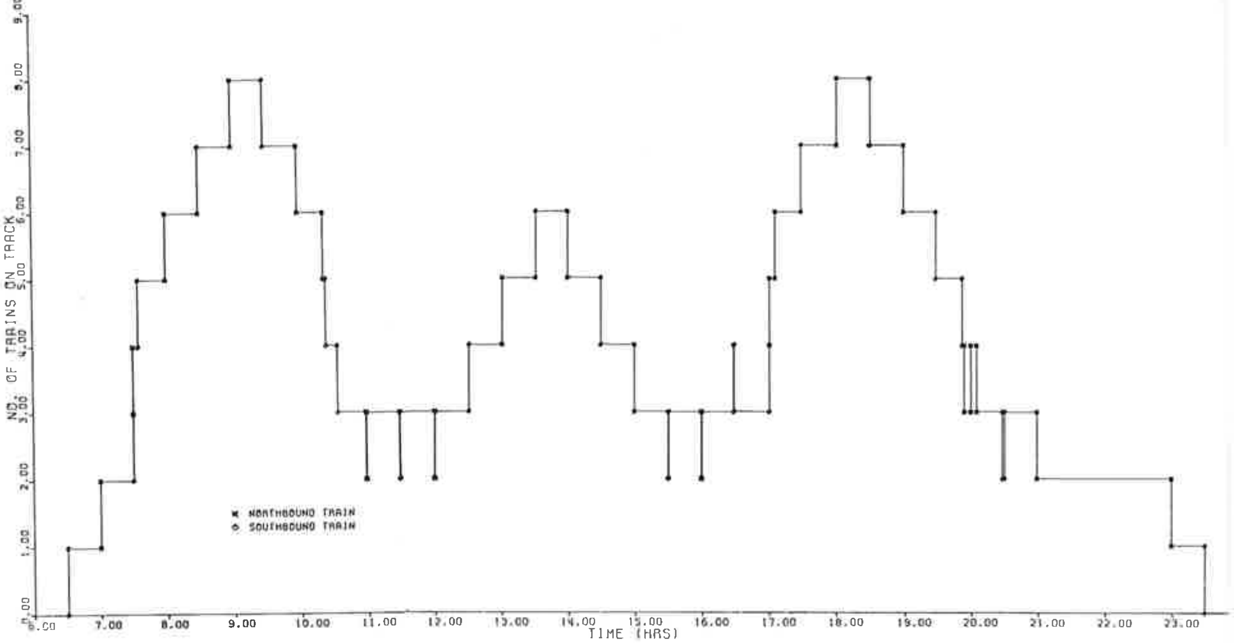



Figure 4.4a Number of Trains on Track Versus Time -- November 1971 Schedule

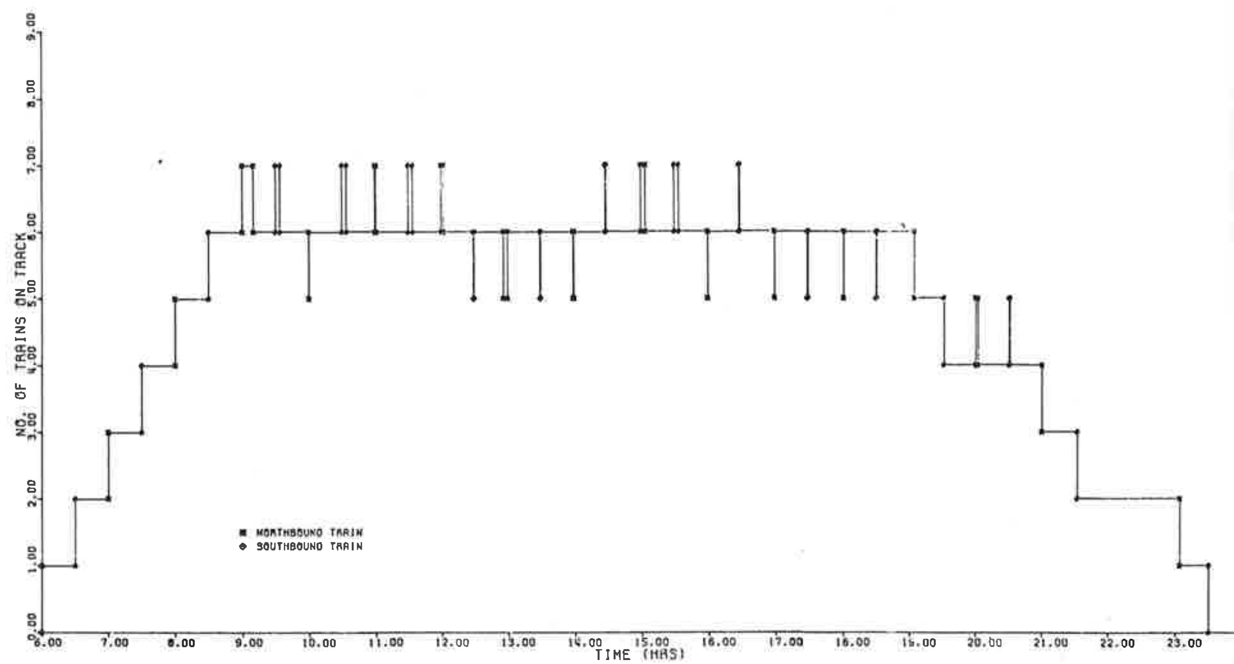



Figure 4.4b Number of Trains on Track Versus Time -- April 1972 Schedule

a. Number of trains,
b. Number of stops made by the train, including departure and arrival, and
c. Time of arrivals at each stop.

4.2.3 Telex Program

This is the main program which shows the distribution of the number of telephone channels available to each train as a function of either time of the day or the distance measured from New York City. The results of this program show the periods of time or the sections of track where the availability of telephone channels is minimum. Figure 4.5a shows a typical plot of the telephone-channel distribution versus time for a morning train starting around 0800 under the November 1971 schedule. Figure 4.5b shows the distribution for a morning train starting around the same time under the April 1972 schedule. A noticeable difference in the distributions exists because of the change in schedule. The change of distribution between the two schedules is even more marked for Train 103 (see Figures 4.6a and b).

In this case, train No. 103 in the November 1971 schedule was only 5 minutes behind another train and the average number of channels was 1.19, while the average number of channels for train No. 103 in the April 1972 schedule was 1.64.

In addition to the above outputs, there are plots and tabulation of the number of trains having access to each channel versus time, and the number of channels available for each train averaged over its run tabulated in ascending order. Figures 4.7a and 4.7b show the number of trains with access to channel 6 for the November 1971 and the April 1972 schedules, respectively. Note that channel 6 under the November 1971 schedule is more congested at certain times and is not as uniformly distributed as under the April 1972 schedule.

A reasonable use of a telephone channel occurs when the channel is accessible to at least one train at all times.

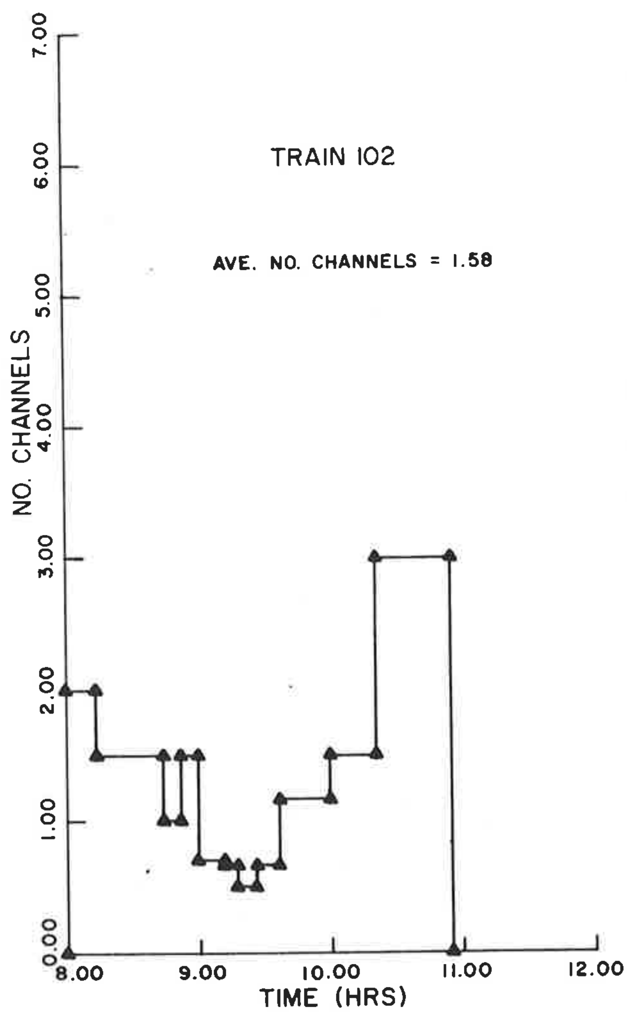



Figure 4.5a Telephone Channel Distribution of Morning-hour Metroliner Train 102 (Starting at 0800 hours) Versus Time -- November 1971 Schedule

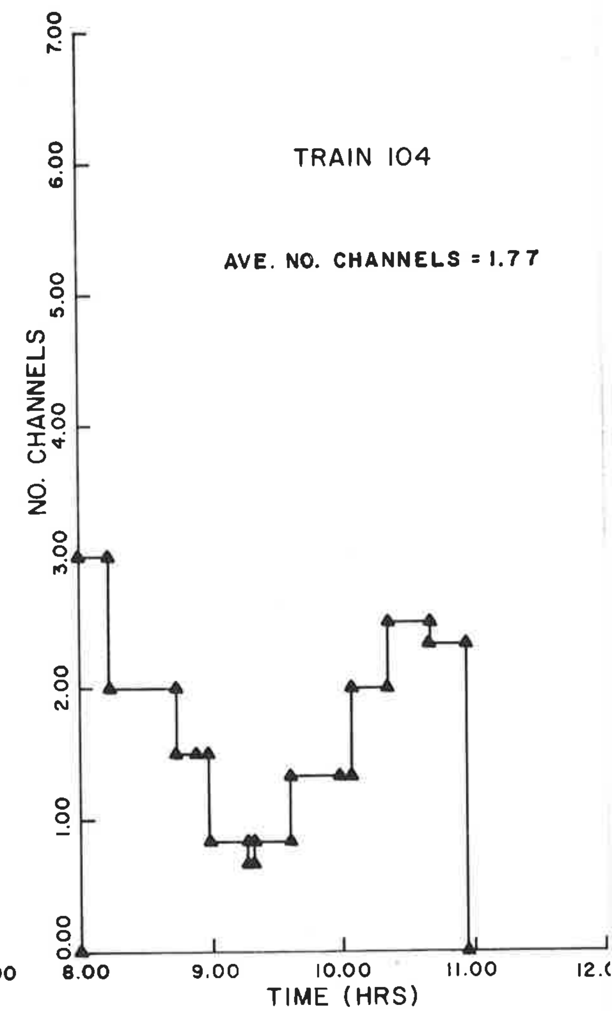



Figure 4.5b Telephone Channel Distribution of Morning-hour Metroliner Train 104 (Starting at 0800 hours) Versus Time -- April 1972 Schedule

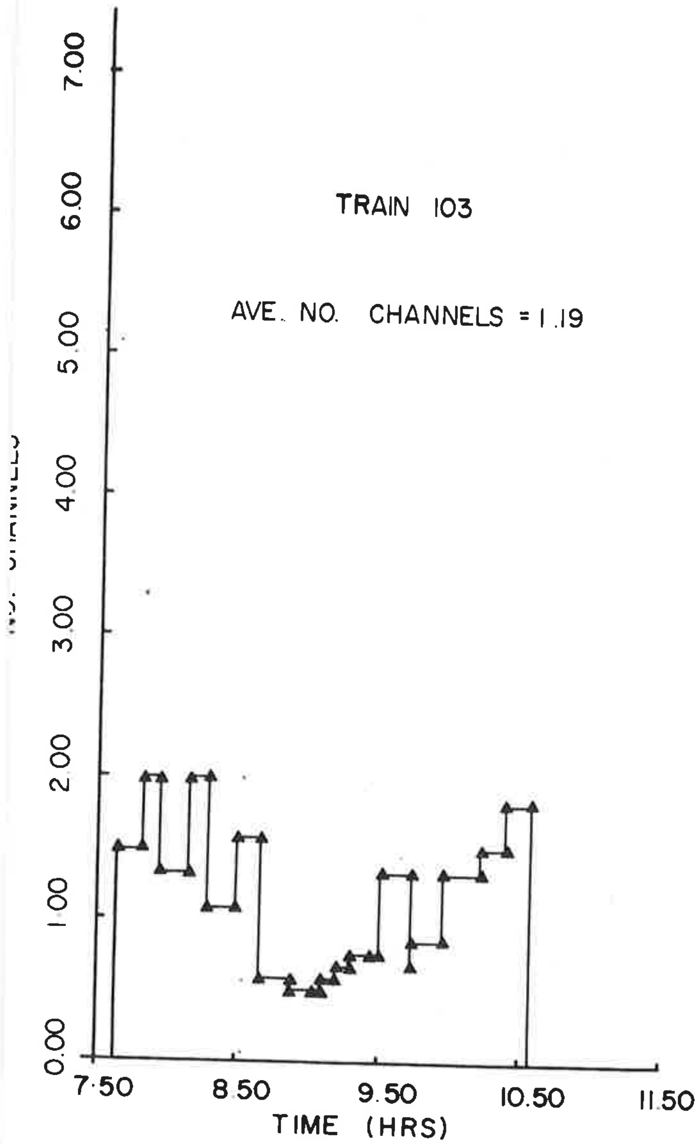



Figure 4.6a Telephone Channel Distribution of Morning-hour Metroliner Train 103 (Starting at 0750 hours) Versus Time -- November 1971 Schedule

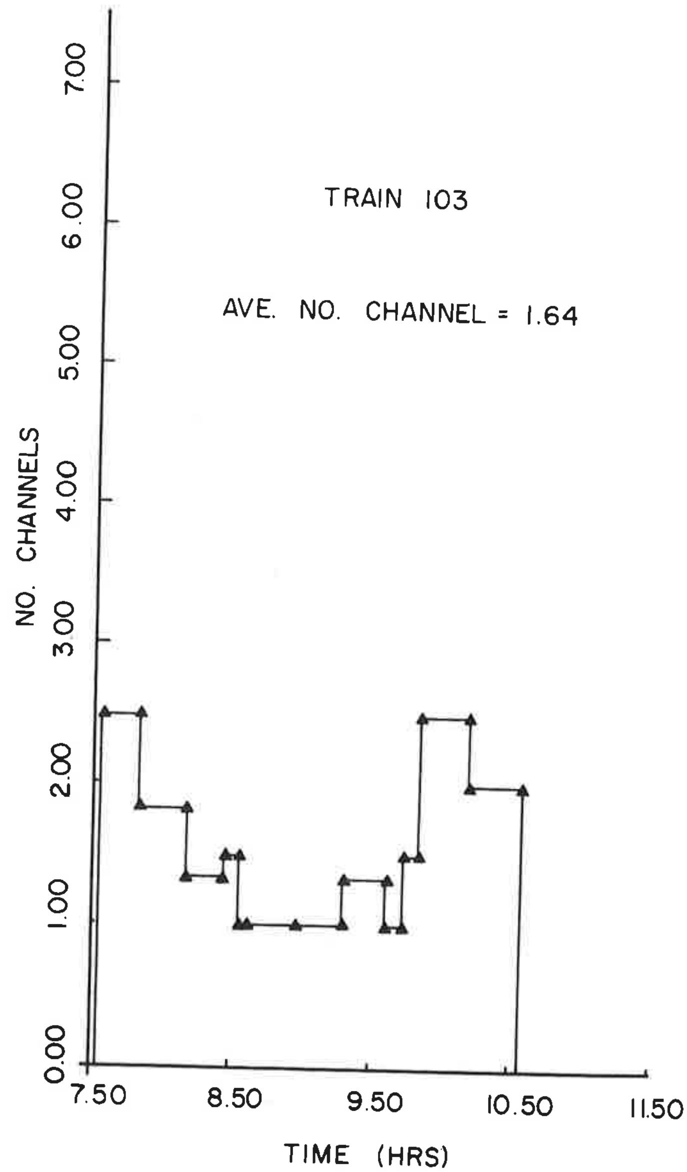



Figure 4.6b Telephone Channel Distribution of Morning-hour Metroliner Train 103 (Starting at 0750 hours) Versus Time -- April 1972 Schedule

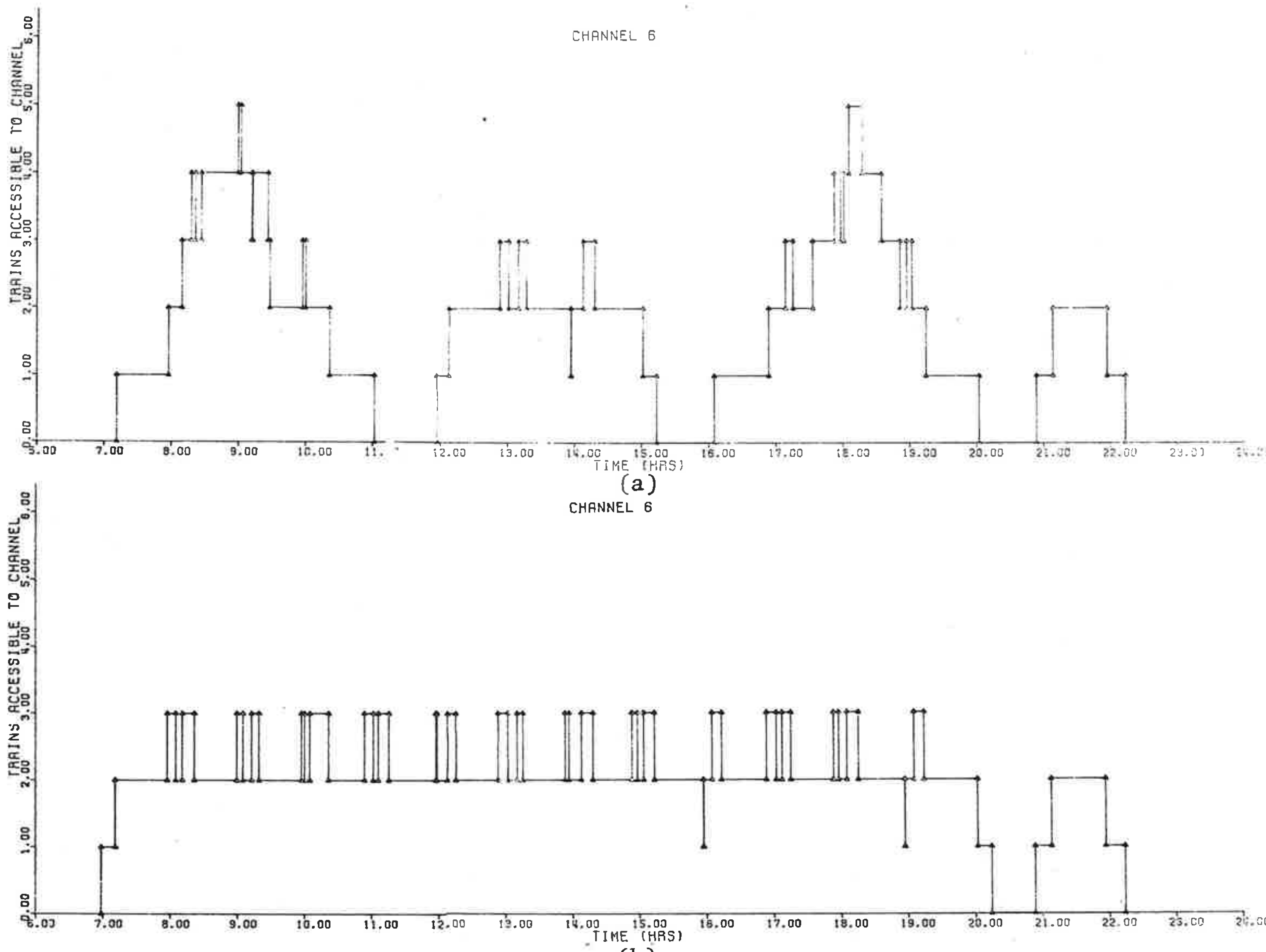



Figure 4.7a&b Number of Trains Accessible to Channel 6 Versus Time -- (a) November 1971; (b) April 1972 Schedule

Figures 4.8a and 4.8b show plots of the number of trains having access to channel 1 for the November 1971 and April 1972 schedules, respectively. Note that for a large portion of the time, there are no trains having access to channel 1. Figure 4.9 shows a plot of the length of time that a certain number of trains had access to channel 1 for the April 1972 schedule. The figure shows that in an 18-hour interval, no trains had access to channel 1 for over 14 hours, while for about 3 hours, 1 train had access to this channel. Figure 4.10 shows a similar plot for channel 2, and Figures 4.11a and 4.11b show similar plots for channel 6 for the November 1971 and April 1972 schedule.

Note the difference of the distribution for channels 6, 2, and 1. It is apparent that some channels have a greater use than others. Channels 1 and 11, for example, in the present system are relatively under-used. A possible remedy is to rearrange the telephone-channel zonal distributions, such that each telephone channel will have uniform loading in terms of number of trains with access to the telephone channel. From the above example, it is clear that the train schedule and the telephone-channel distribution have an intimate interconnection.

With the modification of a train schedule, the distribution of train accessibility may be optimized. The above optimization is, however, beyond the scope of the present report.

The hypothetical demand made by trains on a given telephone channel is not adequately given by the method, resulting in Figures 4.7 and 4.8, since each train also has access to other telephone channels. A more complex model for the loading on a given channel is illustrated as follows: Suppose at a given time three trains - A, B, and C - have access to a given telephone channel, and at this time train A has access to m channels, train B has access to n channels, and train C has access to p channels, then the loading on the given channel

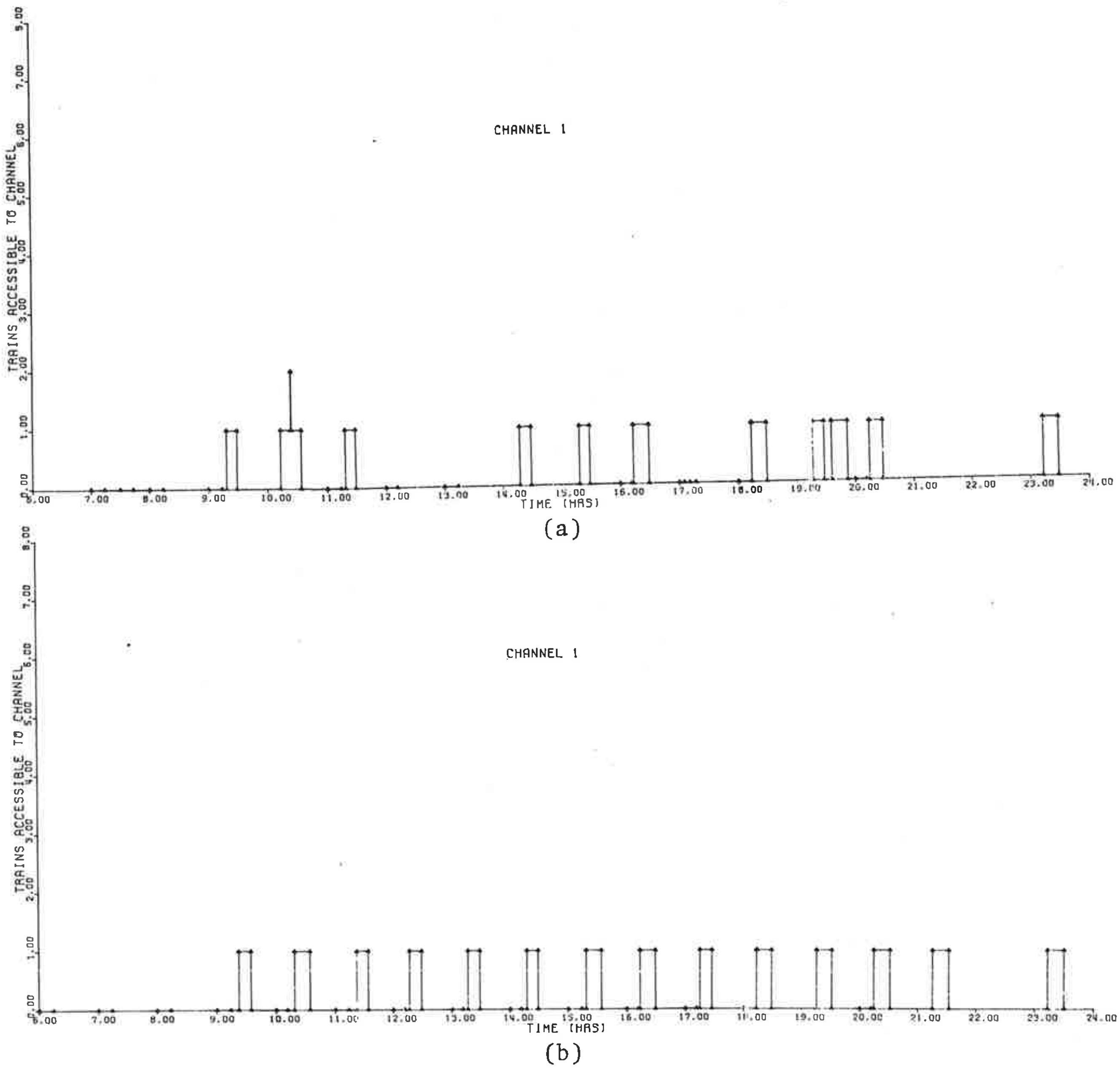



Figure 4.8a&b Number of Trains Accessible to Channel 1 Versus Time -- (a) November 1971; (b) April 1972 Schedule

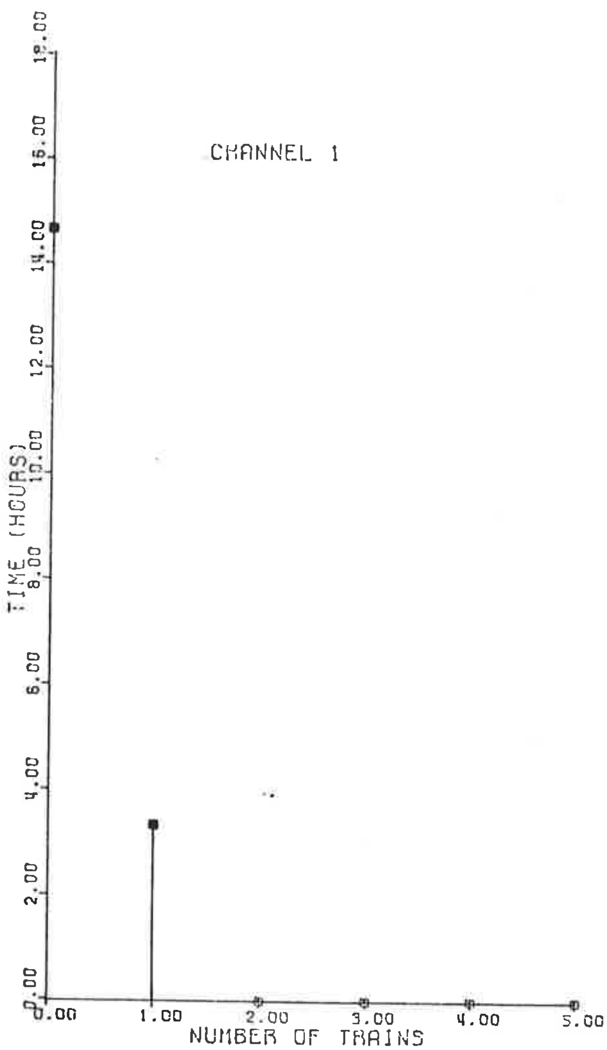



Figure 4.9 Amount of Time That Certain Number of Trains Had Access to Channel 1 -- April 1972 Schedule

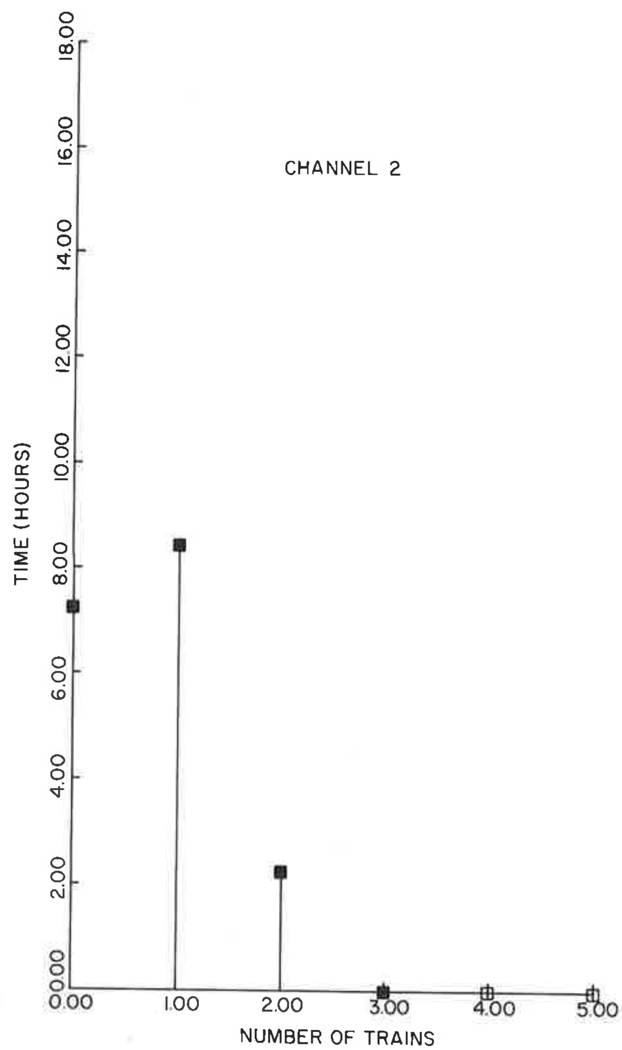



Figure 4.10 Amount of Time That Certain Number of Trains Had Access to Channel 2 -- April 1972 Schedule

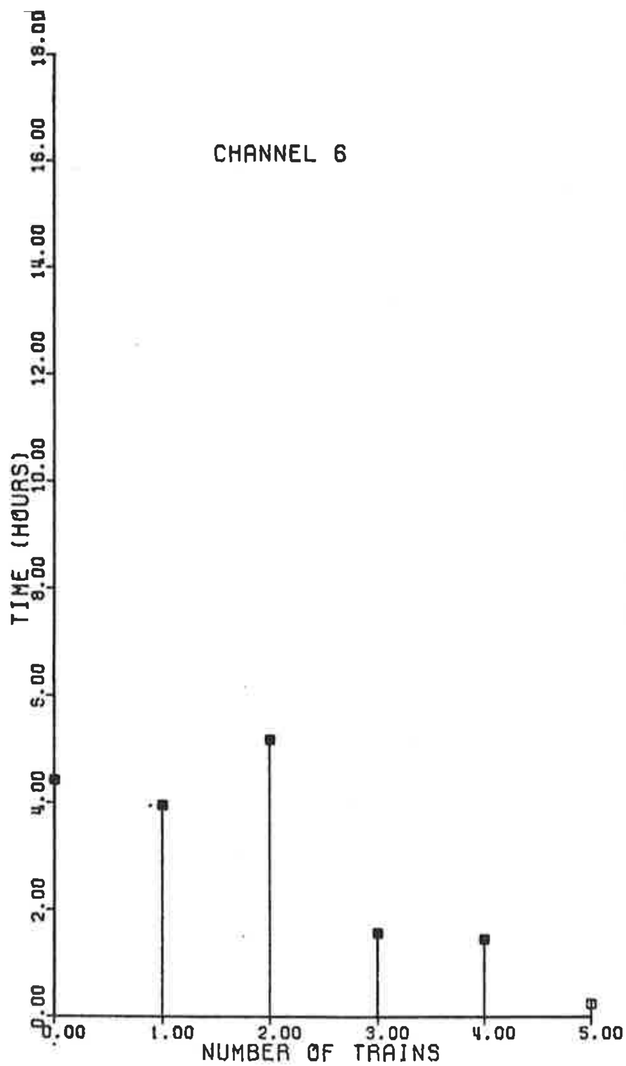



Figure 4.11a Amount of Time That Certain Number of Trains Had Access to Channel 6 -- November 1971 Schedule

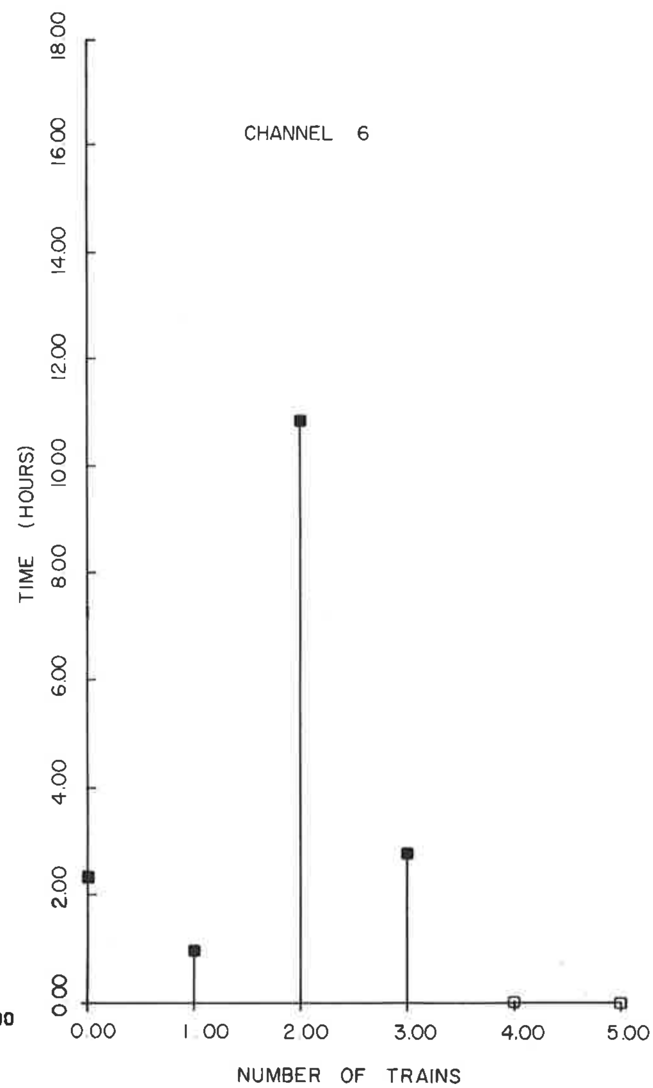



Figure 4.11b Amont of Time That Certain Number of Trains Had Access to Channel 6 -- April 1972 Schedule

by train A is 1/m, by train B is 1/n, etc. The loading on the given channel is given by 1/m+1/n+1/p - that is, sum of the loading from the trains having access to the given channel.

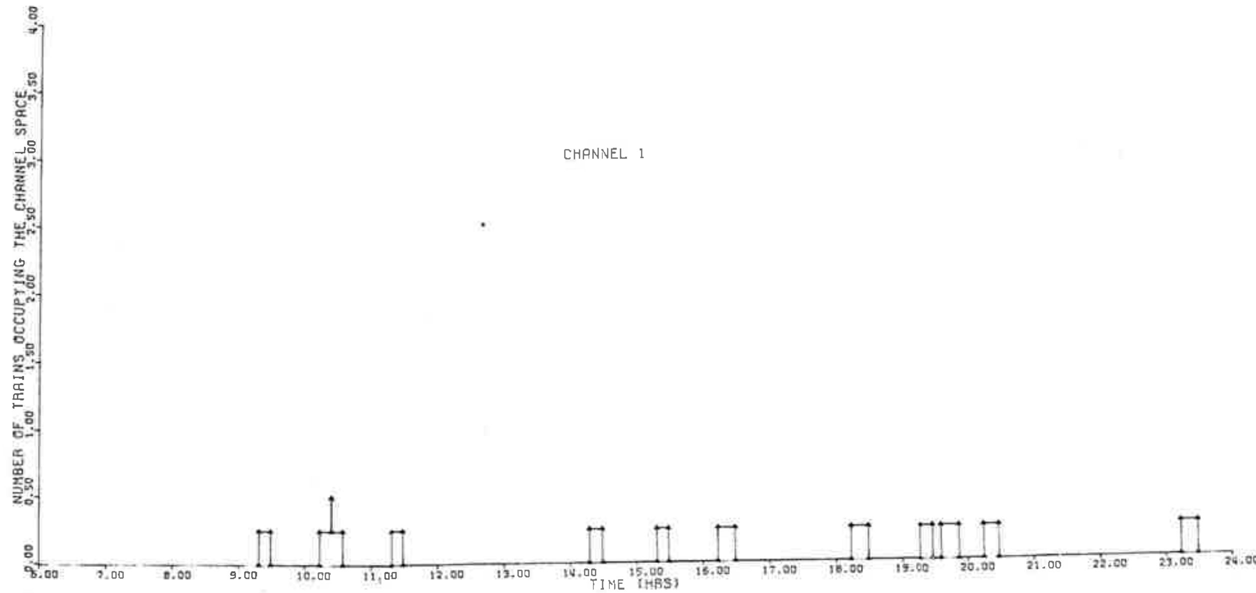
Figures 4.12a and 4.12b show the train-loading demands on channel 1 with this more complex model for the November 1971 and the April 1972 schedules. Similarly, the loading on channel 6 is shown in figures 4.13a (November 1971 schedule) and 4.13b (April 1972 schedule). A comparison of Figures 4.13a and the simple-model Figure 4.4a for channel 6, November 1971 schedule is instructive. For the simple model, a maximum of eight trains has access to this channel. However, since each train also has access to other channels, the maximum loading according to the complex model is about 2.5 trains. Likewise, for the simple model, for the April 1972 schedule, we have a mean of about six trains while with the complex model, which is a more reasonable one, the mean is somewhat over one train for channel 6.

The overall outputs of the program are as follows:

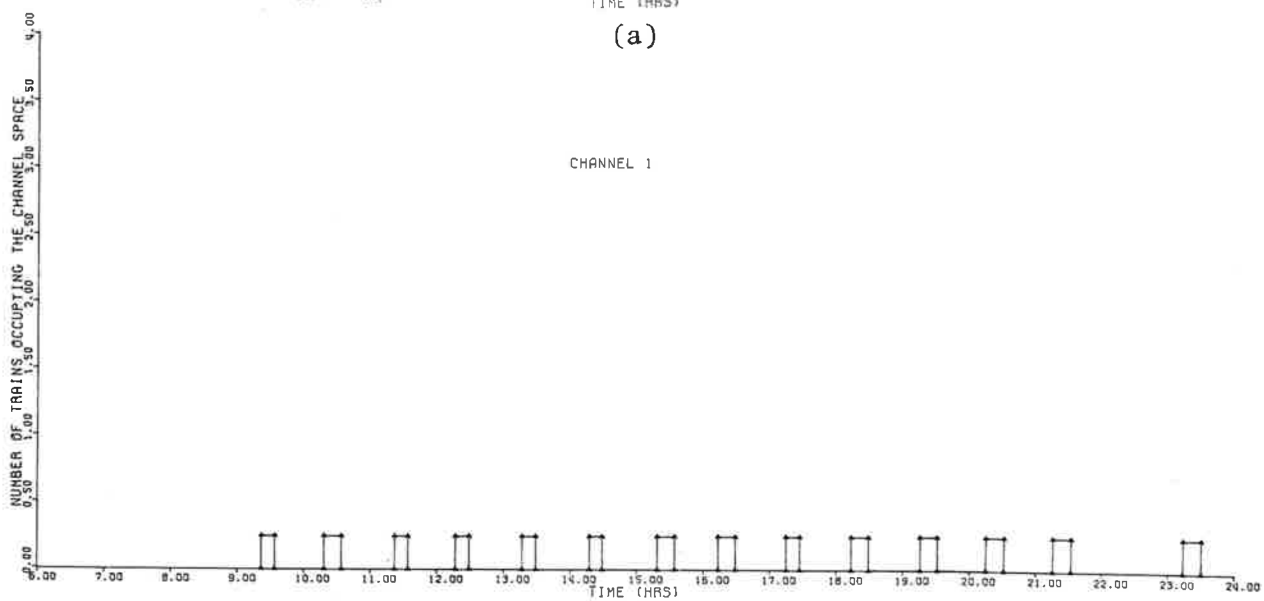
a. Plot and tabulation of the number of trains, with access to each given channel versus time,
b. Plot and tabulation of the average number of channels available to each given train versus time,
c. Plot and tabulation of the average number of channels available to each given train versus distance,
d. The average number of channels available to each given train averaged over its run tabulated in ascending order, and
e. Plot and tabulation of the trains loading on each given channel versus time with the complex-loading model.

## 4.3 REMARKS

The above programs can be used for planning telephone-zone distribution, the number of channels required, the interaction

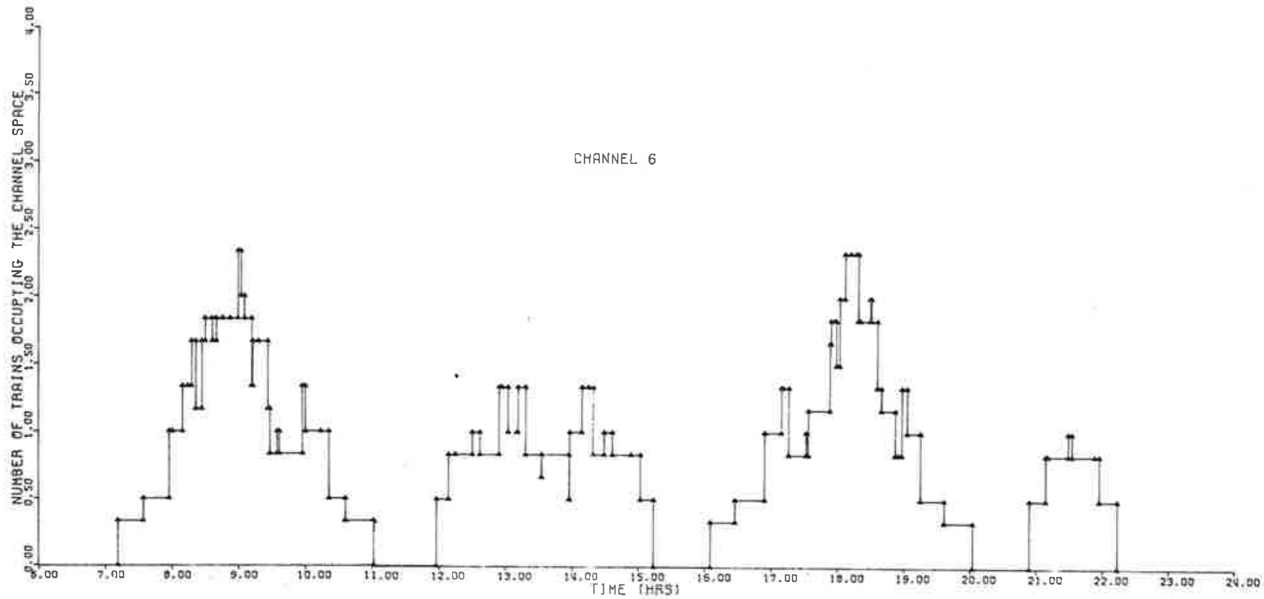



(a)

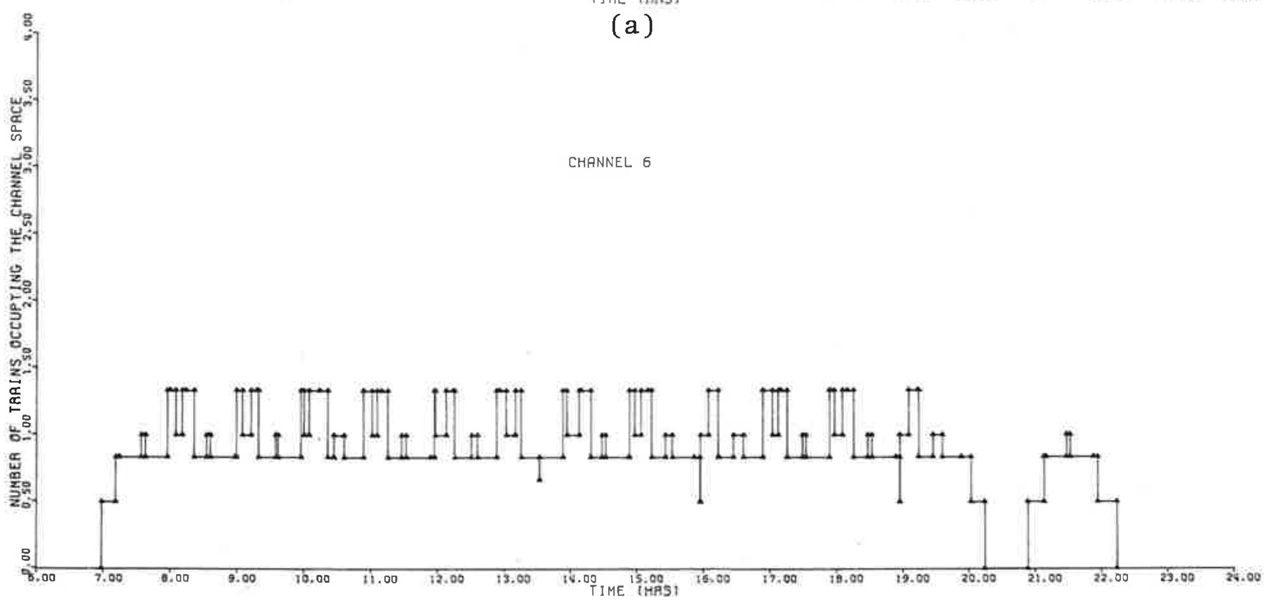



(b)

Figure 4.12a&b Train-loading Demands on Channel 1 -- (a) November 1971; (b) April 1972 Schedule, Complex Model




(a)




(b)

Figure 4.13a&b Train-loading Demands on Channel 6 -- (a) November 1971; (b) April 1972 Schedule, Complex Model of the train schedule with telephone-channel distribution, the minimum number of telephone channels available to each train, and the loading of each individual channel. These programs will be very useful for any new installation on the track. The constraints provided here may present the necessary input to the decision maker on the minimum and optimum channel distribution.

# 5. SUMMARY

The results show that 11.5% of the total passengers used the telephone during a trip. Among the users, a majority or 71% had to wait for either a phone booth or a telephone channel or both. Finally, 73.5% of the passengers believe that telephone service should be provided, 37.2% of the passengers recommend TV, and 19.3% of the passengers are willing to pay for TV.

A direct survey on board the Metroliner train No. 112 conducted on September 30, 1972 has led to the following conclusions: i) a major maintenance problem exists, ii) the demand for telephones is consistent with estimates from AT&T data. Furthermore, three different types of "attempts" have been identified.

Three computer programs were written and can be used for planning a new telephone service system on a new track or for improving the present Metroliner telephone system.

a. The first program is used to compute and plot a space-time diagram of the Metroliner train on the track between Washington D.C. and New York City.

b. The second program is used to compute and plot the total number of trains on the entire track at any given time.

c. The major outputs of the third program consist of 1) the average number of channels available to each train, 2) the loading factor of each individual telephone channel.

# 6. REFERENCES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2. Chin, G.Y., R.E. Eaves, Jr., R.D. Kodis, and P. Yoh, Improvement of Metroliner Telephone Channel Capacity and Modeling of Telephone Channel Demands, Report No. DOT-TSC-FRA-72-2, Transportation Systems Center, Cambridge, MA, March 1972.
3. Roitfarb, A. and R. Shah, Metroliner Telephone Channel Capacity: Program Analysis, Report No. KHL-TSC-72-1026, Scientific Section, Kentron Hawaii, Ltd., Cambridge, MA, November 30, 1972.