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REPORT ON THE TEST AND EVALUATION OF THE DIAL-A-BUS BASIC AND ADVANCED PROGRAMS

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16. Abstract

This is a test report of the Basic and Advanced Dial-A-Ride computer programs developed by Massachusetts Institute of Technology under contract Mass - MTD-6 entitled "Dial-A-Bus".

17. Key Words	18. Distribution Statement
Dial-A-Ride, Dial-A-Bus, Basic Program, Advanced Program	Approved for TSC only. Transmittal of this document outside TSC must have prior approval of the Simulation and Analysis Division of TSC.

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INTRODUCTION

As stated in the Project Plan Agreement UM02, TSC was given the responsibility of reviewing and evaluating the computer software packages that have been developed under the sponsorship of Urban Mass Transportation Administration (UMTA). A program library is to be established that will serve as a repository where these programs could be distributed to potential users and where programming techniques along with analytical methods can be freely exchanged by both the developers and the users.

One of the software packages that has been considered by TSC is the computer programs developed by M.I.T. under contract Mass-MTD-6 entitled "Dial-A-Bus." Two computer programs were developed under this contract, the Basic Program and the Advanced Program.

A letter dated August 25, 1970 from Mr. J. Silien of UMTA authorized TSC to contact M.I.T. and to arrange for the transfer of these two programs as well as any supporting printouts and documentation. The letter further requested that these two programs be tested and evaluated by TSC against the original proposal and the work statement (Appendix C). As such, TSC started taking delivery of this material and worked closely with M.I.T over a period of three months to obtain complete and executable versions. Specifically, the following items were obtained:

- Copy of the Basic Source Program and the Advanced Source Program*
- Copy of the Basic Object Program and the Advanced Object Program (on tape)
- Implementation and User's Guide for the Basic Program and the Advanced Program
- Rough Draft of the Flow-chart of the Basic Program

These programs were tested and evaluated at TSC as part of the UM02 task. Presented in this report are the results of the evaluation effort. An additional effort was expended to generate the necessary data files and operating procedures to facilitate the distribution of these programs to potential users. The operating procedures needed to run the tape

*The ones that were used for the evaluation are currently stored on a TSC disk located at M.I.T.

containing the two programs are given in Appendix D.

This report is organized as follows: The second section gives a brief description of the concept of the Dial-A-Bus and the purposes of the two programs. The result of the evaluation effort is summarized in the next section. The fourth and fifth sections give a detailed check list of the various functional features of the Advanced Program and the Basic Program respectively. Samples of test runs are given in the Appendices.

BRIEF DESCRIPTION OF THE DIAL-A-BUS PROGRAM

The easiest way to describe the concept of Dial-A-Bus is to trace through a typical transaction. A person wishing to make a trip will register his request by a telephone call to central dispatching headquarters. The operator who answers the phone will request the patron's origin and destination. While he waits, the operator will type this information into the computer. Based on this information, the status of the other vehicles and passengers in the system, this new trip will be inserted by the computer in a manner to minimize the inconvenience of other passengers while at the same time attempt to maximize the service to the new customer. Estimated times for the pickup and the delivery will be given to the operator by the computer and the information is in turn transmitted to the customer by the operator over the phone.

The heart of the software system is a dispatching algorithm. This is implemented dynamically in accordance with some prespecified decision criteria based on the current state of the system such as the current vehicle locations, the number of passengers in transit, and the customers that are currently awaiting service. Consideration is given to such things as traffic congestion characteristics at this time of day, the likely impact upon the average trip speed of a typical vehicle, the violation of the estimated time of arrival of each passenger, and the reasonable waiting time that will be tolerated by the customer.

BASIC PROGRAM

The Basic Program is a probabilistic simulator used to evaluate the performance of vehicle routing algorithms. It can be used for planning purposes to test and evaluate the requirements and performance of a Dial-A-Bus type system for any particular urban area. The program contains about 10,000 Fortran instructions (with the exception of a random number generator). The storage requirements for executing the Basic Program in batch mode is approximately 150K bytes. The program can be run on an IBM model 360/40 and up. It can also be executed on any 360/67 time sharing machine with CP/CMS operating system with or without graphics. The graphical mode requires the availability of an ARDS Display and an additional 50K bytes of storage.

ADVANCED PROGRAM

The Advanced Program expands upon the Basic Program to operate in a real-time environment where the customer requests are externally generated. More than 75% of the package in the Advanced Program is the same as that in the Basic Program. The present program requires a core storage of approximately 150K bytes and can be executed on any 360/67 machine with CP/CMS operating system with or without graphics. In general two consoles are required, a console for the operator (input and output) and a console for vehicle dispatching information.

EVALUATION TECHNIQUES

EVALUATION PROCEDURE

The evaluation effort is concentrated on:

1. Loading and executing the programs on the specified computer hardware configurations.
2. Determining whether the programs perform in accordance with the features as detailed in the work statement (Appendix C) and the appropriate implementation and user's guide.

In order to do this, insight had to be obtained with respect to the operating procedures that are required to compile and execute the programs on the IBM 360/67 and 75. This is also necessary since the programs are to become part of TSC's computer program library and made available to those who are working in this field. Operating procedures were generated to compile and execute the programs. Two separate 360/67 systems were used so that the procedures could be judged as to their versatility and adaptability under various versions of the IBM 360/67, CP/CMS operating systems.

The Advanced Program was tested on the 360/67 under the CP/CMS operating system in both the graphic and non-graphic mode and on the 360/67 in the graphic mode. The features of each program were grouped under the following three classifications and tested accordingly:

1. Features required by the work statement
2. Desirable but optional features in the work statement
3. Additional features specifically mentioned in the Implementation and User's Guide.

Test cases were developed to test the input, output, and functional aspects of the program. The input and output commands as summarized in the fourth and fifth sections were employed to exercise the programs in the following manner:

1. To test possible responses to input and output commands (including invalid input commands),
2. To test features considered necessary to an operational Dial-A-Bus program (whether or not stated in the work statement dated June 1970 as included or optional in the Advanced Program),

3. To attempt to overload vehicles (Advanced Program),
4. To attempt to validate the routing algorithm by inputting specific passenger requests chosen in regards to bus locations, projected bus routes, and bus capacity (Advanced Program),
5. To verify input commands pertaining to passenger requests, vehicle contents, and waiting time to evaluate the algorithm response (Basic Program).

No attempt was made to verify the accuracy of the various computational algorithms in the programs. (For example, the dispatching algorithms, statistical computations, etc.) Outputs were deemed acceptable based purely upon engineering judgment.

SUMMARY OF FINDINGS

OPERATING PROCEDURES

Undoubtedly, there will be variations in the IBM 360/CP/CMS operating procedures among computer installations. Some of these variations might prove formidable enough to prohibit a set of prescribed operating procedures from functioning properly as experienced by TSC during the course of this evaluation. Therefore, it would be advisable for TSC to prepare operating guidelines for use during the installation of the programs at various computing facilities.

USER'S GUIDE MATERIAL

The user's guide material provided by M.I.T. is sufficiently adequate to operate the commands of the programs. The contents of this material is well written and clearly illustrated.

FEATURES OF PROGRAMS

Advanced Program

The input and output features of the Advanced Program as specified in the work statement are summarized below:

Information transmitted by the customer to the operator will typically include:

1. Self-identification (e.g., name or identifier code)
2. Origin location
3. Destination location
4. Number of passengers

Information transmitted by the operator to the customer will typically include:

5. Acknowledgment
6. Estimated collection time
7. Vehicle identification number

Typically, information sent to a vehicle by the dispatcher will include:

8. Location of its next stop
9. Number of passengers to be collected or discharged
10. Fare(s) (if stop is a pickup point and fare is to be collected)

11. Logical vehicle number to be displayed

Typical messages from a vehicle are:

12. Message acknowledgement
13. Repeat last transmission
14. Vehicle arrived its assigned stop, request next stop information
15. Vehicle emergency

Of the 15 features given above, the following four features were not included in the Advanced Program:

1. Self-identification (e.g., name or identifier code)

The program acknowledges a service request by assigning a number to a passenger. No name or other means of identification can be used.

6. Estimated collection time

The program does not output this information at the operator's terminal. However, this information can be obtained from the graphical output of the vehicle tour.

11. Logical vehicle number to be displayed

Although the vehicle messages that the computer prints out as being sent by the dispatcher do not include this information, the dispatcher may obtain the information by other means. For example, the information is known to the telephone operator.

15. Vehicle emergency

There are no direct provisions in the program for emergencies such as vehicle breakdowns and the re-assignment of passengers.

Two of the 15 features given above are not computer related or to be found in the program; these are:

12. Message acknowledgment

This is a communication response.

13. Repeat last transmission.

The discrepancies mentioned above are not considered significant enough to severely compromise the purpose of the program.

The Advanced Program, as called for in the Work Statement, can in principle, be used to operate a limited Dial-A-Bus system in a given community on an IBM 360/67 time sharing computer where the program would deploy from seven to ten vehicles by means of accepting a stream of actual customer demands, making routing decisions and out putting messages to the appropriate vehicles, giving their destinations. However, to insure its usability as an operating system in a live demonstration, several additional features would be desirable. For example, on page 17 of the Work Statement, M.I.T. mentioned that the following are desirable features:

1. Restart capability
2. Vehicle breakdown procedures (includes reassignment of passengers)

Examples of additional features that are not in the Work Statement but would be desirable are:

1. System overload (the ability to change the system passenger capacity)
2. Self-identification (e.g., name or identifier code)
3. Vehicle identification number
4. A method of incorporating street addresses, which constitute the operational area
5. Standing requests
6. Automatic billing (if desirable)
7. Provision of a hard copy for use in a manual backup system
8. Additional remote terminals
9. Additional on-line debugging routines

In addition, a manual backup system would have to be available that will allow a Dial-A-Bus system to continue to function at a lower efficiency in the event of computer malfunction.

In the engineering judgment of TSC, the Advanced Program, although operational in accordance with the Work Statement, has limited application potential for use in line demonstrations.

Basic Program

The most important feature of the Basic Program as specified in the Work Statement was the ability to vary parameters such as:

1. Area size
2. Demand level as a function of time
3. Distribution of demands over the service area
4. Mean vehicle velocity between stops
5. Stop time distribution

and to evaluate various operating strategies by changing such parameters as:

1. Number of vehicles
2. Vehicle capacity
3. Nature of service (e.g., many-to-one versus many-to-many service)
4. Maximum allowable waiting times and travel times
5. Heuristic function used to select best vehicle for a given demand
6. Length of test

The above parameters were successfully varied and the input and output commands functional in agreement with the Implementation and User's Guide. Thus the program performed satisfactorily in accordance with its designed objectives and operational constraints.

DETAILED ANALYSIS OF THE ADVANCED PROGRAM

The Advanced Program as delivered operates as follows*:

1. Accepts input requests containing a destination, location, number of passengers, and priority of demand (P and R commands).
2. Assigns passengers to vehicle according to heuristic routing algorithms considering proximity, projected tour, and occupancy of bus and delay due to insertion of new request incurred by passengers expecting pickup and those already on the bus.
3. Issues dispatching messages to inform bus of next stop on tour. However, no messages regarding number of passengers to pickup or fare to collect are output. (P and R command)
4. Accepts input commands to simulate the buses arrival at its next appointed stop (V command) and the computer response with another vehicle dispatching message; also simulates that a bus has arrived at a stop and finds more passengers than expected (A command).
5. Accepts input commands to cancel a previously requested trip (C command).
6. Accepts input commands to display delay times of passengers and vehicles (W and O commands).
7. Accepts input commands to display present bus locations, projected bus tours, and projected passenger tours. (X, Y, Z commands).
8. Accepts input commands to maintain display (E command) and to monitor program to give offline printing of major system statistics (M, N, S commands).

The following test plan contains a detailed evaluation of each feature and each input-and-output command as summarized above. The test plan has been organized into three segments:

1. Features required by the work statement dated June, 1970 (Appendix C)
2. Features that are desirable but optional in the work statement
3. Additional features specifically mentioned in the Implementation and User's Guide.

*A detailed description of the commands and the individual features can be found in the Advanced Program Implementation & User's Guide, July, 1970.

The first column lists the features. The second and third columns contain respectively the date the feature was tested and its status (available or not available). The last column contains a brief description and comments as to its use.

DIAL-A-BUS ADVANCED PROGRAM TEST PLAN

I. Features Required by the Work Statement, Dated June 1970, P. 17, 18

Features	Date Tested	Status	Comments
A. Customer request information input by operator			
1. Self-identification (e.g., name or identifier code)	11/20/70	N.A.*	No self-identification. Identification provided by computer assigning a number to the passenger.
2. Origin location	11/20/70	A**	Inputted using the P and R Commands (see III 3).
3. Destination location	11/20/70	A	Inputted using the P and R commands (see III 3).
4. Number of passengers	11/23/70	A	Inputted using the P command (see III 3). The R command assumes only one passenger.
B. Computer operated information transmitted by operator to customer			
1. Acknowledgement of service request and estimated collection time	11/20/70	A	The program acknowledges a service by assigning a number to the passenger and giving an estimated collection time.

**Available
*Not Available

2. Vehicle identification number	11/19/70	N.A.	There are no present means to provide vehicle identification numbers to the passenger. Such identification would be required to handle situations where people at the same stop were assigned to different vehicles.

C. Information generated by computer sent from dispatcher to vehicle

1. Vehicle commands (e.g., V, pick up or drop off)	11/23/70	A	The vehicle commands can be sent to a second terminal or can be printed at the operator's terminal. The following commands cause printing at the second terminal corresponding to commands to the bus driver: R, P, V, C.
2. Location of its next stop	11/20/70	A	Message generated following the input of the V command.
3. Number of passengers to be collected or discharged.	11/20/70	N.A.	No message to this effect is generated at the dispatcher's terminal.
4. Fare(s) (if stop is a pickup point and fare is to be collected)	11/20/70	N.A.	No fare is indicated at the dispatcher's terminal.
5. Logical vehicle number to be displayed	11/20/70	N.A.	The vehicles have preassigned numbers that remain fixed during the run.

D. Information received by the operator from the vehicle

1. Message acknowledgement.		N.A.	Messages are assumed by the program as being acknowledged. This is the question of vehicle dispatcher

			communication, not operator-computer communication.
2. Repeat last transmission		N.A.	A question of vehicle-dispatcher communication.
3. Vehicle arrived at its assigned stop, request next stop information		A.	The V command informs the program that the vehicle has arrived at the next stop as described in the I. and U.G. There is no input command to handle a vehicle emergency. Late vehicle information is generated by the computer.

II. Features that are desirable but optional in the work statement dated June 1970, p. 17.

Features	Date Tested	Status	Comments
1. Restart capability		N.A.	This feature is a function of the teleprocessing communications control program and not of an application program like the advanced program. It must be incorporated into the teleporcessing control program which should be considered as part of the computer operating system.
2. Cancellation of a service request	11/20/70	A	Performed by the C command (see III 3)
3. Accommodating more passengers at a stop than expected	11/20/70	A	Performed by the A command (see III 3). The assumption is made by the computer that all additional passengers taken from this stop have the same destination.

4. Vehicle breakdown (includes re-assignment of passengers)		N.A.	There appears to be no procedure available in the Implementation and User's Guide to accommodate break-downs.
5. Detection of late vehicles (both for internal compilation purposes and break-down suspicion)	11/19/70	A	The program handles this by means of the W command as described in the Implementation and User's Guide and by printing messages when vehicles are overdue at five minute intervals.
6. Priority classes	11/20/70	A	Performed by the P command (see III 3).
7. System overload		N.A.	In order to provide for this feature, the FT02 file which initialized the program and remains constant throughout program execution must be modified. This requires a termination of the present program, modification to the FT02 file, and a new version of the program to begin execution (work statement P.3)

III. Additional features specifically mentioned in the <u>Implementation and User's Guide</u>, date July 1970.

Features	Date Tested	Status	Comments
1. The heuristic routing algorithm	11/19/70-11/23/70	A	The program does assign passengers to vehicles in a deter-ministic manner.
2. Input file FT02F001 for initialization		A	The FT02 file must be modified prior to execution. However, the Implementation and User's Guide does

Features	Date Tested	Status	Comments
			not indicate the file format necessary for modification (see II 7)
3. General commands (e.g., RXXXX, customer service request)	11/23/70	A	R - Simulates passenger requests inputted at terminal as described in I. & U.G.
		A	P - Simulates multiple requests and/or priority classes. Although not described in I. & U.G., a description of use obtained at later date, 11/25/70
		A	O - Used to determine time vehicles expected at their next stop, as described in I. & U.G.
		A	M - Turns on monitoring switches and writes out trace information, as described in I. & U.G.
		A	N - Turns off monitoring switches
		A	A - Informs program that bus finds unexpected number at a stop, as described in I. & U.G.
		A	C - Cancels a passenger request, as described in I. & U.G.

Features	Date Tested	Status	Comments
		A	E - Erases the ARDS display scope and places the city map in the center of the screen leaving the lower quarter for input commands, it is actually a display command.)
		A	S - Offline prints major system statistics, as described in I. & U.G.
		A	Q - Terminates simulation run and gives full I/O, as described in I. & U.G.
4. Passenger information (e.g., X, plot trip on ARDS)	11/20/70	A	W - Displays desired trips of passengers who have waited longer than a certain time specified by the operator.
		A	X - Plots desired trip of passenger, as described in I. U.G.
		A	Y - Displays projected tour of passenger as assigned to specific bus, as described in I. & U.G.
5. Vehicle information (e.g., last reported position of vehicle)	11/20/70	A	Z - Displays projected tour of vehicle, as described in I. & U.G.
		A	Z all - Displays last known position of each bus,as described in I. & U.G.

DETAILED ANALYSIS OF THE BASIC PROGRAM

The Dial-A-Bus Basic Program is a simulation program that can be operated in either an interactive time-sharing mode using an IBM 360/67 with CP/CMS or in the batch processing mode using an IBM 360 system. The program is a probabilistic simulator used to evaluate the performance of routing algorithms for a Dial-A-Bus system. It does this by generating demands for service from probabilistic distributions selected by the user. Demands are then assigned to a particular vehicle by the user specified routing algorithm. As the vehicles collect and deliver their assigned passengers, statistics are gathered on system performance and service quality.

The Basic Program is designed so that a transportation planner can tailor Dial-A-Bus to a particular urban environment. More specifically, the Basic Program allows the planner to set various conditions and study the productivity and performance of Dial-A-Bus under various strategies. The following external parameters are set:

1. Area size
2. Demand level as function of time
3. Distribution of demands over the service area
4. Mean vehicle velocity between stops
5. Stop time distribution

Then, various operating strategies can be evaluated using parameters such as:

1. Number of vehicles
2. Vehicle capacity
3. Nature of service, (e.g., many-to-one versus many-to-many service)
4. Maximum allowable waiting times and travel times
5. Heuristic function used to select best vehicle for a given demand
6. Length of test

Given these external and operational parameters, the Basic System will internally generate passenger demands at random intervals at point coordinates within the service area and assign the demands to vehicles in accordance with the decision rules input by the planner. When the test is complete, statistics relating to the system performance are outputed.

Typical output statistics include:

1. Mean level of service (ratio of the average service time, i.e., waiting time plus travel time, to direct driving time)
2. Vehicle productivity in passenger trips per vehicle hour
3. Mean vehicle occupancy
4. Maximum waiting time

The planner would then vary his input in his search for an optimal Dial-A-Bus configuration for the particular environment in question.

Some of the more important commands available in the Implementation and User's Guide are outlined as follows:

ERAS	Erases ARDS display, sets a new grid	graphics only
CONT	User wants the program to compute for x minutes where x is specified by the time interval	graphics only
TIME X	Program will compute for x minutes of run time as specified by the time interval x	graphics only
STAT	Major statistics are displayed on the screen. Included are number of passengers, number of pickups, run time, demands generated, average vehicle times, % time vehicle empty, % time vehicles unassigned, plus maxima, minima, waiting time, travel time, etc.	graphics only
FULL	All input-output up to this point of the program is printed offline (at the computer center).	graphics only
QUIT	Terminates the run, offline prints all input-output.	graphics only
PASP X	Trip desired by x to be plotted on the ARDS	graphics only
WAIT X	Desired trips of all passengers who have waited more than x minutes	graphics only
W8TD X	Desired trips of all passengers being carried who have waited more than x minutes is displayed	graphics only
W8TD ALL	Desired trips of all passengers in vehicles will be displayed	graphics only

VEHI ALL	Last reported position of each vehicle is displayed	graphics only
VEHI X	Projected tour of the vehicle as is currently known	graphics only
ASSN X	X is a passenger number. If a passenger is assigned to vehicle y, this command is the same as VEHI	graphics only
HIST X	Displays what vehicle did prior to the present time	graphics only
INSE	The run proceeds until the time at which the next demand is scheduled to arrive	graphics only
MANU	Similar to INSE but new assignment does not take place	graphics only
STOM	Run time is incremented and entire vehicle tour chosen by the algorithm will be displayed	graphics only
ACCE	Informs the algorithm which vehicle of those displayed will pick up the most recent demand	graphics only
ACCE ALL	Algorithm picks the "best" vehicle to do the pickup	graphics only

The following test plan contains a detailed evaluation of each feature and each input or output command of the program. The test plan has been organized into two segments:

- Features required by the work statement dated June, 1970 (Appendix C)
- Additional features specifically mentioned in the Implementation and User's Guide.

The first column lists the features. The second and third columns contain respectively the date the feature was tested and its status (available or not available). The last column contains a brief description and comments as to its use.

DIAL-A-BUS BASIC PROGRAM TEST PLAN

I. Features Required by the Work Statement, Dated June 1970, Pgs. 9 and 10

Features	Date Tested	Status	Comments
A. External parameters	1		
1. Area size	12/7/70	A	This feature is defined by giving the X and Y coordinates of the lower left hand and upper right hand corners of the rectangular zone as specified on p.21-22 of the I. & U.G. and is contained in the FT02F001 input file
2. Demand level as a function of time	12/7/70	A	This feature is initialized by the variable NDEM as specified on p. 7 of the I. & U.G. and contained in the FT02F001 input file.
3. Distribution of 12/7/70 demands over the service area	12/7/70	A	The distribution of demands in generated by two random number generators, one for the X coordinate and the other for the Y coordinate, as specified on p. 18, distribution 3 and 4 of the I. & U.G. and contained in the FT02F001 File.
4. Mean Vehicle Velocity between stops	12/7/70	A	This feature is defined by the variable SPEED as specified on p. 9 of the I. & U.G. and contained in the FT02F001 file.
5. Stop time Distribution	12/7/70	A	This feature is supplemented by specifying a distribution as specified on p. 18 of the I. & U.G. and contained in the input file FT02F001.

Features	Date Tested	Status	Comments
B. Operating strategies as experimental parameters			
1. Number of Vehicles	12/7/70	A	This feature is defined by the variable MAXVEH as specified on p. 6 of the I. & U.G. and contained in the FT02F001 file.
2. Nature of service (e.g., many- to-one versus many-to many)	12/7/70	A	This feature is defined by the variable NDROP as specified on p. 14 of the I. & U.G. and contained in the FT02F001 file.
3. Vehicle capacity	12/7/70	A	This feature is defined by the variable VCAP as specified on p. 8 of the I. & U.G. and contained in the FT02F001 file.
4. Maximum allowable waiting times and travel times	12/7/70	A	These features are defined by the variables PWATCN (1), PGETBY (1), PBYGET (1), PMTLC (1), and PATLC (1), as specified on p. 11 of the I. & U.G. and contained in the FT02F001 file.
5. Heuristic function used routing algorithm	12/7/70	A	The program does assign passengers to vehicles in a deterministic manner.
6. Length of test	12/7/70	A	This feature is defined by the variable TIMEND as specified on p. 9 of the I. & U.G. and contained in the FT02F001 file.
C. Output Statistics			
1. Mean level of service (ratio of the average service time, i,e., waiting time plus travel time to direct driving time)	12/7/70	A	These features and other vital statistics are given in the program output as indicated on p. 25 of the I. & U.G. An example of some of the statistics are contained on page 13, 14 of Appendix B.

Features	Date Tested	Status	Comments
2. Mean productivity in passenger trips per vehicle hour			
3. Mean vehicle occupancy			
4. Minimum waiting time			

II. Additional Features Specifically Mentioned in the Implementation and User's Guide, Dated July 1970

Features	Date Tested	Status	Comments
1. Input file FT02F001 (initialization)	12/7/70	A	Before the Basic Program can be executed, it is necessary to provide input data which defines what conditions are being simulated. This is done by setting up an input file on the time-sharing account. This file is named; File FT02F001, where "file" is the file name and "FT02F001" is the file type (Reference p. 3 of I. & U.G.)
2. General (e.g., in display mode)	12/7/70	A	The general commands pertaining to the graphic mode of operation are given by the variables ERAS, CONT, TIME X, STAT, FULL, and QUIT as specified on p. 31 of the I. & U.G.
3. Passenger	12/7/70	A	The passenger commands pertaining to the graphic mode of operation are given by the variables PASP X, WAIT X, and W8TD X, as specified on p. 31 of the I.& U.G.
4. Vehicle	12/7/70	A	The vehicle commands pertaining to the graphic mode of operation are given by the variables VEHI ALL, VEHI X, ASSN X, and HIST X as specified on p. 35, 36 of the I. & U.G.

Features	Date Tested	Status	Comments
5. Interactive	12/7/70	A	The interactive commands pertaining to the graphic mode of operation are given by the variables INSE, MANV, STOM, and ACCE as specified on p. 38, 39 of the I. & U.G.
6. Console	12/7/70	A	The basic commands to execute the program from the graphic and non-graphic mode of operation are given on p. 22, 29 of the I. & U.G.

APPENDIX A

ADVANCED PROGRAM CASES

- Explanation of test 1 input and output
- Test 1
- Test 2

The easiest way to understand the test cases would be to indicate, command by command, the input required and the computer response. All data on a line preceded by a carrot (>) is inputted by the operator; all other information is generated by the program. Messages and/or data preceded by "FROM TOYE:" are the vehicle dispatching messages. Theoretically, the inputting of commands handling passenger requests etc. will occur at one terminal and the dispatching messages at another terminal where they will be relayed to the drivers by means of radio communication.

The following is a step by step description of test 1.

1. a. The carrot (>) indicates the program expects some input.
   b. R is put in to indicate a passenger request.
   c. The computer responds with a carrot expecting an origin (2 Bow St.).
   d. The computer again returns a carrot expecting a destination (25 Acorn St.).
   e. The messages generated by the computer are (1) the dispatching message indicating vehicle 005 should pick up passenger 0001 at 2 Bow St. and (2) at time 0.15 (program starts at time = 0.00) passenger 1 will be picked up in four minutes. The first message would be relayed to driver of bus 005 and the second message relayed by the operator to the waiting passenger who phoned in the request.
2. a. The second request is to go from 4 Ames St. to 20 Arrow St.
   b. The computer assigns bus 001 to pick up this passenger (passenger 0002).
3. a. The third request, from the Faculty Club to the Sub shop, results in a different message.
   b. The vehicle dispatching message is:
   001 0002000300030002.
   c. The 001 indicates that the passenger has been assigned to vehicle 001. The tour of the bus is given by the rest. The first time the number appears indicates that passenger being picked up; the second time the passenger number appears indicates a delivery. Therefore, vehicle 001 will pick up passenger 0002, pick up passenger 0003, drop off passenger 0003, and drop off passenger 0002. As the vehicle has already been given a command to pick up passenger 0002 in a previous request and has not completed that mission, there is no new pickup or dropoff command to be issued to the driver.

4. a. Request 4 is a multiple request requiring the P command.
   b. When the computer answers with a carrot, input a carriage return
   c. The message ENTER NUMBER AND PRIORITY OF DEMAND is generated
   d. The numbers 22 are entered indicating two people going class two
   e. At this point the origin and destination of the request is inputted
   f. Then the computer responds with the pickup time, delivery time, and cost for each class
   g. The R command following was incorrect and should have been a carriage return thus causing:
   h. The vehicle dispatching message and the expected pickup time to appear
   i. Both passengers are assigned the same passenger number (0004).
5. Note at the top of page A5 of test 1 a message: VEHICLE 5 IS 5.62 MINUTES LATE FOR ARRIVAL AT 2 BOW ST. These messages occur as delays of greater than 5, 10, 15 minutes etc. result.
6. a. The 4th command (v6) on page A5 indicates to the computer that vehicle has arrived at his next appointed stop and is waiting further information.
   b. The "FROM TOYE:" message informs the driver of his next stop.

The above step by step guidance should assist in better understanding the test case and the input and output commands. Test case 2 contains just the "FROM TOYE:" messages sent to another terminal. The input commands were made on an ards display terminal, and thus, could not be saved.

```
>RI                               TEST NO. 1
 WARMSTART OR COLDSTART?
 PLEASE ENTER YOUR NAME AND THE CURRENT DATE
 ENTER SIMULATION TIME INTERVALS FOR DISPLAY ENTRY
 THANK YOU
* RETURN FROM SETUP
 TABLES BUILT
 PLEASE ENTER INITIAL LOCATIONS OF   7 VEHICLES
 VEHICLE   1
 VEHICLE   2
 VEHICLE   3
 VEHICLE   4
 VEHICLE   5
 VEHICLE   6
 VEHICLE   7
 RETURN FROM INITL
 CALL MODEL
>R
>2 BOW ST
>25 ACORN ST
  FROM TOYE:   VEHICLE 005 :PICKUP PASSENGER   0001 AT 2 BOW ST
  0.15-- PASSENGER   1 EXPECTED PICKUP IN  4 MINS
>R
>4 AMES ST
>20 ARROW ST
  FROM TOYE:   VEHICLE 001 :PICKUP PASSENGER   0002 AT 4 AMES ST
  1.05-- PASSENGER   2 EXPECTED PICKUP IN  4 MINS
>R
>FACULTY CLUB
>SUB SHOP
  FROM TOYE:  001      0002000300030002
  1.70-- PASSENGER   3 EXPECTED PICKUP IN  5 MINS
>P
>
 ENTER NUMBER AND PRIORITY OF DEMAND
>22
>SUB SHOP
>11 GRANT ST
 CLASS 1:  P   3.5,   D   9.2  FOR $0.43
 CLASS 2:  P   3.5,   D   9.2  FOR $0.60
>R
  FROM TOYE:  VEHICLE 006 :PICKUP PASSENGER   0004 AT SUB SHOP
  2.37-- PASSENGER   4 EXPECTED PICKUP IN  4 MINS
>B #U BRIDGE
 THERE DO NOT EXIST   0 VEHICLES - TRY AGAIN
>R
>BU BRIDGE
>10 GRANITE ST
  FROM TOYE:  VEHICLE 004 :PICKUP PASSENGER   0005 AT BU BRIDGE
  4.78-- PASSENGER   5 EXPECTED PICKUP IN  3 MINS
>P
>MIT
>JOYCE CHEN
 CLASS 1:  P   7.5,   D  10.2  FOR $0.19
 CLASS 2:  P   7.5,   D  10.2  FOR $0.26
>
  FROM TOYE:  004      0005000600060005
  5.80-- PASSENGER   6 EXPECTED PICKUP IN  5 MINS
```

```
>R
 VEHICLE   5 IS  5.62 MINUTES LATE FOR ARRIVAL AT 2 BOW ST
>202 MAIN ST
>570 MASS AV
  FROM TOYE:  001      0002000300070003000070002
  6.87-- PASSENGER   7 EXPECTED PICKUP IN  6 MINS
>M
 VEHICLE   1 IS  5.82 MINUTES LATE FOR ARRIVAL AT 4 AMES ST
>N
>V6
 VEHICLE   6 IS  5.46 MINUTES LATE FOR ARRIVAL.AT SUB SHOP
  FROM TOYE:   VEHICLE 006 :DELIVER PASSENGER  0004 AT 11 GRANT ST
>V5
  FROM TOYE:   VEHICLE 005 :DELIVER PASSENGER  0001 AT 25 ACORN ST
>A2
 HOW MANY PASSENGERS AT THIS STOP?
>5
 SEVERE ERROR - END OF TOUR FOR VEHICLE  2 FOUND BEFORE DELIVERY OF PAS
 MONITOR SWITCHES TURNED ON
>N
 VEHICLE   4 IS  5.97 MINUTES LATE FOR ARRIVAL AT BU BRIDGE
>A4
 HOW MANY PASSENGERS AT THIS STOP?
>5
 VEHICLE    4 OKAY TO PICKUP    5 PASSENGERS AT CURRENT STOP
>V#A1
 HOW MANY PASSENGERS AT THIS STOP?
>9
 VEHICLE    1 SCHEDULED TO PICKUP    1PASSENGERS CAN PICKUP    8 PEOPLE
 OW MANY PEOPLE SHOULD HE PICK UP?
>8
 VEHICLE    1 OKAY TO PICKUP    8 PASSENGERS AT CURRENT STOP
>S
 INTERMEDIATE I/O AT TIME =     13.167 FOR RUN    1
>V2
 VEHICLE   1 IS 11.82 MINUTES LATE FOR ARRIVAL AT 4 AMES ST
 VEHICLE   2 IS NOT SCHEDULED - TRY AGAIN
>V1
* FROM TOYE:   VEHICLE 001 :PICKUP PASSENGER   0003 AT FACULTY CLUB
>V6
  FROM TOYE:   VEHICLE 006  IS NOW UNASSIGNED
>V3
 VEHICLE   3 IS NOT SCHEDULED - TRY AGAIN
>  V1
   IS AN UNKNOWN COMMAND - TRY AGAIN
>V1
  FROM TOYE:   VEHICLE 001 :PICKUP PASSENGER   0007 AT 200 MAIN ST
>V1
  FROM TOYE:   VEHICLE 001 :DELIVER PASSENGER  0003 AT SUB SHOP
>V1
 VEHICLE   4 IS 11.00 MINUTES LATE FOR ARRIVAL AT BU BRIDGE
  FROM TOYE:   VEHICLE 001 :DELIVER PASSENGER  0007 AT 570 MASS AV
```

```
>V4
 FROM TOYE:  VEHICLE 004 :PICKUP PASSENGER   0006 AT MIT
>V4
 FROM TOYE:  VEHICLE 004 :DELIVER PASSENGER  0006 AT JOYCE CHEN
>Q
    FULL I/O AT TIME      17.233 FOR RUN     1
  VEHICLE CONTENTS - AVERAGE, VARIANCE, MAXIMUM     PERCENT TIME EMPTY
*
 COMPOSITE VEHICLE AVERAGE CONTENTS=  0.35 AND PER CENT TIME EMPTY=.861,
    7 DEMANDS REPRESENTING    -13 PASSENGERS HAVE OCCURRED WITH AN AVERAG
    7 PICKUPS AND     2 DELIVERIES HAVE BEEN MADE, LEAVING   -15 PASSENG
 THE MEAN LEVEL OF SERVICE IS  3.15


 STATISTICS FOR DEMANDS IN PRIORITY CLASS    1 :
COMPOSITE STATISTICS FOR    2 DEMANDS AND    2 PASSENGERS:
                                              BY DEMAND
                                WAITING TIME  TRAVEL TIME   TOTAL TIME
 MEAN                              10.233        2.933        13.167
 VARIANCE                          11.903        6.334         0.871
 NORMALIZED MEAN                    0.003        0.333         0.531
 WEIGHTED NORMALIZED MEAN           0.103        0.015         0.194
 NO. OF CONSTRAINT VIOLATIONS       0            0             0            0
 NORMALIZED VIOLATION TIME          0.0          0.0           0.0          0
 MAXIMUM                           13.683        5.450        14.100
 MINIMUM                            6.783        0.417        12.233
 NORMALIZED MAXIMUM                 0.138        0.656         0.886
 NORMALIZED MINIMUM                 0.501        0.010         0.115


 STATISTICS FOR DEMANDS IN PRIORITY CLASS    2 :


 STATISTICS FOR DEMANDS IN PRIORITY CLASS    3 :


 STATISTICS FOR DEMANDS IN PRIORITY CLASS    4 :
 IGTOT=    0 IGORG=    0 IGDES=    0 IGNO=    0 IGEMPY=    0
 WITHIN TOUR    3 UNASS VEHI    4 END OF TOUR    4
 ALL CHOICES BAD    0 CONSTRAINTS VIOLATED BY ASSIGNMENT
 TOTAL    0 TRAVEL    0 WAITING    0
 BAD CHIOCE WHEN LEGAL CHOICE AVAILABLE    0
10.51.26 OFFLINE PRINTCC FILE FT08F001
10.51.46 ERASE FILE FT08F001
10.52.19 ERASE FILE FT07F001
10.52.23 STAT
P-DISK:  1600 RECORDS IN USE, 648 LEFT (OF 2248), 71% FULL (OF 15 CYL.)
R; T=9.08/77.10 10.52.26
>LOGOUT
T=9.11/78.10 10.52.54
CP ENTERED.
```

A-6

TEST NO. 2

```
SLEEP
 FROM TOYE:   VEHICLE ØØ5 :PICKUP PASSENGER    ØØØ1 AT 2 BOW ST
 FROM TOYE:   VEHICLE ØØ1 :PICKUP PASSENGER    ØØØ2 AT 1 MAIN ST
 FROM TOYE:   ØØ1      ØØØ2ØØØ3ØØØ3ØØØ2
 FROM TOYE:   ØØ1      ØØØ2ØØØ3ØØØ3ØØØ4ØØØ2ØØØ4
 FROM TOYE:   ØØ5      ØØØ1ØØØ5ØØØ1ØØØ5
 FROM TOYE:   VEHICLE ØØ6 :PICKUP PASSENGER    ØØØ6 AT 3 DOCK ST
 FROM TOYE:   VEHICLE ØØ3 :PICKUP PASSENGER    ØØØ7 AT 38 HENRY ST
 FROM TOYE:   ØØ3      ØØØ7ØØØ7ØØØ8ØØØ8
 FROM TOYE:   ØØ6      ØØØ6ØØØ9ØØØ6ØØØ9
 FROM TOYE:   ØØ3      ØØØ7ØØØ7ØØØ8ØØ1ØØØ1ØØØ8
 FROM TOYE:   VEHICLE ØØ4 :PICKUP PASSENGER    ØØ11 AT 2 OSBORN ST
 FROM TOYE:   VEHICLE ØØ7 :PICKUP PASSENGER    ØØ12 AT JOYCE CHEN
 FROM TOYE:   VEHICLE ØØ2 :PICKUP PASSENGER    ØØ13 AT CITY HALL
 FROM TOYE:   VEHICLE ØØ1 :PICKUP PASSENGER    ØØØ3 AT FACULTY CLUB
 FROM TOYE:   VEHICLE ØØ2 :DELIVER PASSENGER   ØØ13 AT 64 STATE ST
 FROM TOYE:   VEHICLE ØØ3 :DELIVER PASSENGER   ØØØ7 AT 1 HASTINGS SQ
 FROM TOYE:   VEHICLE ØØ4 :DELIVER PASSENGER   ØØ11 AT 20 PACIFIC ST
 FROM TOYE:   VEHICLE ØØ5 :PICKUP PASSENGER    ØØØ5 AT 2 HOLYOKE ST
 FROM TOYE:   VEHICLE ØØ5 :DELIVER PASSENGER   ØØØ1 AT 1Ø LOPEZ ST
```

Output from second terminal used in conjunction with the ARDS display.

```
P
>LOGOUT
 SHIFT CONNECT    TOTAL    VIRTUAL
   1   1:Ø9:1Ø   Ø:Ø6.26   Ø:ØØ.ØØ
LOGOUT AT 11.24.ØØ ON 11/2Ø/7Ø
```

APPENDIX B

BASIC PROGRAM TEST CASES

- Output description
- Sample of FT002F001 File
- Sample Output

This appendix contains teletype printout of the test cases used in the evaluation, which are summarized as follows: a description of the input data file FT02F001, a sample file FT02F001, and a description of sample teletype output.

Before the basic program can be executed, it is necessary to provide input data which defines what conditions are being simulated. This is done by setting up an input file on time-sharing account. This file is named

FILE FT02F001

A complete sample input file FT02F001 used to generate the teletype material in this appendix is contained on page , titled "Sample File FT02F001."

Each program parameter is specified by data in the input file FT02F001. For example, the x and y coordinates for area size are line 21.

0.	0.	3.	3.	1	1
1.	1.	2.	2.	1	1
1.	1.	1.	1.	1	1

The mean vehicle velocity between stops is specified by the variable SPEED listed under line 5 as 4.0. Stop time distribution is listed as one of the 12 distributions specified on p. 18, 19 of the I. & U.G. In the enclosed example on line 16, the 1 generates a uniform distribution which determines random numbers between 0 and 1. Complete details of each parameter and its associated format are specified on pages 5-22 of the I. & U.G.

On page 5 the first eight lines pertain to the procedures used in initializing the test case. The 9th line "RUN NOARDS NOMAP" gives the specific command for loading this program from the disk into the core of the computer as specified on page 22, 23 of the I. & U.G. The term "NOARDS" refers to the teletype mode of operation. Line 10 and 11 is a message referring to the status of the program. The line starting "P DISK" to the line starting "EXECUTION BEGINS" is information pertaining to the loading of the subroutines. The following line "COLD" indicates the initial status of this run followed by the request for name and date. Page 6B "SIMULATION INPUT DATA" pertains to data in the FT02F001 input file. The following lines containing the term "TIME =" relate to the specific times the status of conditions of service are outputted. Page 7B completes the time intervals specified by the input file.

Pages 8B and 9B refer to a printout of the variables contained in the FT02F001 input file as initiated on line 9 of page 9B "PRINTF FILE FT02F001." Pages 10B, 11B and 12B illustrate the printout of the output file containing the statistics that were generated during the execution of the test case. It was initiated by line 9, page 10B "PRINTF FILE FT02F001."

Some of the commands used to execute the graphical aspects of the test case are outlined below:

1) TIME 1.
2) TIME 5.
3) PASP 1.
4) PASP 10.
5) PASP 25.
6) PASP 50.
7) PASP 75.
8) WAIT 5.
9) W8TD 5.
10) VEHI 2.
11) ASSN 10.
12) HIST 4.

Statistics generated during the graphical mode or operation are offline printed on the 360/67 printer. Some of the statistics that can be obtained are given on page . Generally, these statistics are similar to the output generated on the teletype. For example, see the teletype statistics on page .

SAMPLE FILE FT02F001

```
CARD COLUMN 1
  |
  |COMMENT: THIS IS A SAMPLE FT02F001.  ON LINE 5 THE NUMBER
  |COMMENT: OF VEHICLES IS 12, THE CAPACITY IS 20, THE SPEED
  |COMMENT: IS 15 MPH.  ON LINE 4 THE OBJECTIVE FUNCTION IS 4.
 1|DATA STARTS HERE
 2|01    5  00.0
 3|   12   20   20   12   12
 4| 0 3    4   00
 5| 0  12 20  4.0 0.01 30. 150.    0.0
 6| 0.50 1.50
 7| 1      65741  1.0
 8|999. 9.9  99.  9.9 999.
 9|  0.0  0.0  11  0.0
10| 0 0 C  00.  00.   15.
11| 1 01212
12|   2.   2.   1.0
  |COMMENT: THE LINE NUMBER AT THE LEFT CORRESPONDS TO THOSE
  |COMMENT: IN THE DISCUSSION ABOVE.  THESE ARE NOT INCLUDED
  |COMMENT: IN THE ACTUAL INPUT FILE.
14|DISTRIBUTIONS START HERE
15|   65729   1
  |   65759   1
  |   65771   1
  |   65789   1
  |   65897   1
  |   65735  -1
  |   65791   1
  |   65807   1
  |   65747   1
  |   65819   1
  |   65847   1
  |   65863   1
16| 1 0.000 1.000 1
  | 1 0.000 1.000 2
  | 1 0.000 1.000 3
  | 1 0.000 1.000 4
  | 6 1.000 0.000 5
  | 3 0.667 0.000 6
  | 1 0.250 0.500 7
  | 1 0.250 0.500 8
  | 6 1.000 0.000 9
  | 1 0.000 1.00010
  | 1 0.000 1.00011
  | 1 0.000 1.00012
  |COMMENT: LINE 20 INDICATES THAT THERE IS 1 ZONE
```

```
  |COMMENT: LINE 21 INDICATES THE ZONE IS 3 BY 3 MILES
17|GEOGRAPHICS STARTS HERE
18|    5.0  1
19|  1
20|  3
21|   0.    0.    3.    3.   1   1
  |   1.    1.    2.    2.   1   1
  |   1.    1.    1.    1.   1   1
```

```
CP/67 VERSION 2.0-21  11/25/70

>LOGIN TOY2
ENTER PASSWORD:
>9245
READY AT 17.42.26 ON 12/07/70

>IPL CMS
CMS..VERSION 2.0-16 11/25/70
>RUN NOARDS NOMAP

SEEMS TO WORK NOW
    -TREVOR

P-DISK:  1454 RECORDS IN USE, 794 LEFT (OF 2248), 65% FULL (OF 15 CYL.)
17.43.21 LOAD MAIN BLOCK DAMASS DEMAND ASSIGN ARRIVE DLCHCK CANCEL
 THE FOLLOWING NAMES ARE UNDEFINED:
      IDISP    MDISP    GDAMAS   AINIT    SALRM    OTEST    AERASE   ARDS
      ACSIZE   SDATL    BINEBC   STPOS    PTEXT
 !!! E(00004) !!!
17.44.02 USE CARADD CHTIM CIRCM2 CIRCUM CONS NEW WIPE DEPART
 THE FOLLOWING NAMES ARE UNDEFINED:
      IDISP    MDISP    GDAMAS   AINIT    SALRM    OTEST    AERASE   ARDS
      ACSIZE   SDATL    BINEBC   STPOS    PTEXT
 !!! E(00004) !!!
17.44.28 USE EXPNTL FINISH FIXTIM UNIF3 GEO GEOEFF GEOSET INITL INTIO PSS
 THE FOLLOWING NAMES ARE UNDEFINED:
      IDISP    MDISP    GDAMAS   AINIT    SALRM    OTEST    AERASE   ARDS
      ACSIZE   SDATL    BINEBC   STPOS    PTEXT
 !!! E(00004) !!!
17.44.56 USE INTOUR MOVE MODEL NOPLAC NPOSN OBJINT OUTOUR PSEUDO PUNCHO B
 THE FOLLOWING NAMES ARE UNDEFINED:
      IDISP    MDISP    GDAMAS   AINIT    SALRM    OTEST    AERASE   ARDS
      ACSIZE   SDATL    BINEBC   STPOS    PTEXT
 !!! E(00004) !!!
17.45.23 USE WRITE RESCHD RLOGR RNRML RTRN SCHED SETUP SYSTAT UNIFRM VSTA
 THE FOLLOWING NAMES ARE UNDEFINED:
      IDISP    MDISP    GDAMAS   AINIT    SALRM    OTEST    AERASE   ARDS
      ACSIZE   SDATL    BINEBC   STPOS    PTEXT
 !!! E(00004) !!!
17.45.50 USE RAND EXTRAP POINT SAVE DIST TREVOR GDAMAS VDUMP SEARCH
 THE FOLLOWING NAMES ARE UNDEFINED:
      IDISP    MDISP    GDAMAS   AINIT    SALRM    OTEST    AERASE   ARDS
      ACSIZE   SDATL    BINEBC   STPOS    PTEXT
 !!! E(00004) !!!
 THE FOLLOWING NAMES ARE UNDEFINED:
      AERASE   ARDSW    ACSIZE
EXECUTION BEGINS...
 WARMSTART OR COLDSTART?
>COLD
 PLEASE ENTER YOUR NAME AND THE CURRENT DATE
>R. MONTANARI, 12/07/70
 THANK YOU
```

```
          SIMULATION INPUT DATA

   VEHICLE CHARACTERISTICS

12 VEHICLES OF CAPACITY  20

   AREA CHARACTERISTICS:

 3.0 BY  3.0 MILE AREA

  89 DEMANDS PER HOUR

INPUT DATA READ AND WRITTEN
RETURN FROM INITL
SIMULATION TIME       0.0


TIME =      15.000
NO DEMANDS BEING OBSERVED HAVE REACHED THEIR DESTINATIONS


TIME =      30.000
NO DEMANDS BEING OBSERVED HAVE REACHED THEIR DESTINATIONS


TIME =      45.000
NO DEMANDS BEING OBSERVED HAVE REACHED THEIR DESTINATIONS


TIME =      60.000
   33 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  2.96
THE WEIGHTED LEVEL OF SERVICE IS  2.17


TIME =      75.000
   36 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  2.80
THE WEIGHTED LEVEL OF SERVICE IS  2.59


TIME =      90.000
   41 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  2.79
THE WEIGHTED LEVEL OF SERVICE IS  2.56


TIME =     105.000
   45 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  2.70
THE WEIGHTED LEVEL OF SERVICE IS  2.65


TIME =     120.000
   26 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  2.83
THE WEIGHTED LEVEL OF SERVICE IS  2.67
```

```
TIME =     135.ØØØ
   43 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  2.93
THE WEIGHTED LEVEL OF SERVICE IS  2.71


TIME =     150.ØØØ
   33 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  2.98
THE WEIGHTED LEVEL OF SERVICE IS  2.7Ø


TIME =     165.ØØØ
   33 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  3.ØØ
THE WEIGHTED LEVEL OF SERVICE IS  2.77


TIME =     180.ØØØ
   34 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  3.Ø1
THE WEIGHTED LEVEL OF SERVICE IS  2.84


TIME =     195.ØØØ
   3Ø DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  3.Ø1
THE WEIGHTED LEVEL OF SERVICE IS  2.84


TIME =     199.333
   35 DEMANDS ON THE SYSTEM
THE MEAN LEVEL OF SERVICE IS  3.Ø2
THE WEIGHTED LEVEL OF SERVICE IS  2.88
WARMSTART OR COLDSTART?
>COLD
IHC218I
TRACEBACK FOLLOWS-    ROUTINE    ISN    REG. 14
                      IBCOM             A2Ø125C8
                      MAIN              ØØØØ36D6
ENTRY POINT= ØØØ12ØØØ
$$FILE FT38FØØ1 HAS BEEN OFFLINE PRINTED BUT NOT ERASED
P-DISK:  1655 RECORDS IN USE, 593 LEFT (OF 2248), 74% FULL (OF 15 CYL.)
R; T=35.Ø4/66.62 17.51.49
>LOGOUT X
T=35.Ø6/67.15 17.52.12
CP ENTERED.

>LOGOUT X
 SHIFT CONNECT    TOTAL    VIRTUAL
   1   Ø:1Ø:16   1:Ø7.Ø2   Ø:35.Ø1
LOGOUT AT 17.52.22 ON 12/Ø7/7Ø

CP/67 VERSION 2.Ø-21  11/25/7Ø
```

```
CP/67 VERSION 2.0-21  11/25/70
C
>LOGIN TOY2
ENTER PASSWORD:
>9045
READY AT 17.57.36 ON 12/27/72

>IPL CMS
CMS..VERSION 2.2-16 11/25/72
>PRINTF FILE FT02F001

SEEMS TO WORK NOW
     -TREVOR

P-DISK:  1655 RECORDS IN USE, 593 LEFT (OF 2248), 74% FULL (OF 15 CYL.)

DATA STARTS HERE
01    5  00.0
   20   20   20   20   20   20
 2 3    4  000
 0  12 22  4.0 0.01 30. 150.  00.0
 0.50 1.00  4.0
 1     65741  1.0
 10. 1.5   5.  1.5  15.
  0.0  0.0  11  0.0
 0 0 0   0.    0.    15.
 0 01212
DISTRIBUTIONS START HERE
   65729   1
   65759   1
   65771   1
   65789   1
   65895   1
   65735  -1
   65795   1
   65807   1
   65747   1
   65819   1
   65847   1
   65865   1
 1 0.000 1.000 1
 1 0.000 1.000 2
 1 0.000 1.000 3
 1 0.000 1.000 4
 6 1.000 0.000 5
 3 0.667 0.000 6
 1 0.250 0.500 7
 1 0.250 0.500 8
 7 0.100 1.900 9
 1 0.000 1.00010
 1 0.000 1.00011
 1 0.000 1.00012
COMMENT: GEO DATA IS NOW READ IN MILES F5.2
GEOGRAPHICS STARTS HERE
    4.2  1
  1
  1
   0.   0.   3.   3.  1  1
```

```
     SERVICE CHARACTERISTICS:

 0.5  MINUTES PICKUP AND DELIVERY TIME PER PASSENGER
THERE ARE    1  PRIORITIES OF SERVICE
   THE PROBABILITY SEED USED TO GENERATE PRIORITY CLASSES IS:
           65741


FOR PRIORITY CLASS    1:
 10.0 WAITING TIME CONSTRAINT (MINS)
  1.5*STRGHT +  5.0 TRAVEL TIME CONSTRAINT (MINS)
  1.5*STRGHT + 15.0 TOTAL TIME CONSTRAINT (MINS)
 DEMANDS IN THIS PRIORITY CLASS ARE GENERATED  1.000  FRACTION OF THE I


  OUTPUT CHARACTERISTICS:

  0.0 COMPLETE OUTPUT (MINS)
 15.0 INTERMEDIATE OUTPUT (MINS)
  0.0 DISPLAY ENTRY (MINS)
  0.0 SIMULATED PERIOD (MINS)


  ALGORITHM OPTIONS SPECIFIED:

STATISTICS WILL BE TAKEN FOR DEMANDS  ARISING BETWEEN  30. AND 150. (MI
MINIMUM TRIP 0.50 MILES
DISTANCE ADJUSTMENT 1.20*STRGHT
MINIMUM ALLOWED VALUE OF LINK FACTOR 0.0  (PER CENT)
  11 INITIAL DEMANDS
ACCESS TIME (IN MINUTES)  4.00
OBJECTIVE FUNCTION:   4 REQUESTED AT TIME   0.0
ARET=(A*POOL(INP+TNDELV)+1)*ALONGP+(B*POOL(IND+TNDELV)+1)*ALONGD
OBJECT=ARET+GTIM(1)
 PROBABILITY SEEDS
  65729    1

  65759    1

  65771    1

  65789    1

  65895    1

  65735   -1

  65795    1

  65807    1

  65747    1

  65819    1

  65847    1

  65865    1

MAXIMUM NUMBERS ALLOWED DURING COURSE OF RUN:
```

```
CP/67 VERSION 2.0-21  11/25/72

>LOGIN TOY2
ENTER PASSWORD:
>9045
READY AT 18.10.51 ON 12/07/72

>IPL CMS
CMS..VERSION 2.0-16 11/25/72
>PRINTF FILE FT08F001

SEEMS TO WORK NOW
    -TREVOR

P-DISK:  1655 RECORDS IN USE, 593 LEFT (OF 2248), 74% FULL (OF 15 CYL.)

1  RUN NUMBER  1 WITH   5 BLOCKS OF HISTORY
 PROBABILITY FUNCTIONS
  DISTRIBUTION      A        B       SEED
          1       0.0     1.000      1
          1       0.0     1.000      2
          1       0.0     1.000      3
          1       0.0     1.000      4
          6       1.000  0.0         5
          3       0.667  0.0         6
          1       0.250  0.500       7
          1       0.250  0.500       8
          7       0.100  1.900       9
          1       0.0     1.000     10
          1       0.0     1.000     11
          1       0.0     1.000     12
 THE TRAVEL LENGTH DISTRIBUTION CONSISTS OF    1 STEPS OF    4.20 MILES W
 THE WEIGHTING FACTORS RELATING THE CHOICE OF A GIVEN STEP ARE
   1
 THE AREA IS DIVIDED INTO   1 ZONES
  THE ZONE COORDS AND THEIR RELATIVE PROBABILITIES OF CONTAINING ORIGINS
      X1        Y1        X2        Y2     ORIGIN WEIGHT    DESTINATION WEIGHT
    0.0      0.0      3.00      3.00              1                    1
DR. MONTANARI, 12/07/72


           SIMULATION INPUT DATA

    VEHICLE CHARACTERISTICS

  12 VEHICLES OF CAPACITY  20

  SPEED: 4.00 (MINUTES PER MILE)

    AREA CHARACTERISTICS:

   3.0 BY  3.0 MILE AREA

    89 DEMANDS PER HOUR

  THERE ARE    0 DISPATCHING POINTS AND    0 DISTINCT DESTINATIONS
```

```
VEHICLES      DISPATCHING POINTS      STATIONS      SEEDS      DISTRIBUTIO
   20                 20                 20           20            20

INITIAL LOCATION FOR VEHICLE  1 IN "UNITS" (X,Y) =   154  154
INITIAL LOCATION FOR VEHICLE  2 IN "UNITS" (X,Y) =   111  221
INITIAL LOCATION FOR VEHICLE  3 IN "UNITS" (X,Y) =   275  155
INITIAL LOCATION FOR VEHICLE  4 IN "UNITS" (X,Y) =   263   40
INITIAL LOCATION FOR VEHICLE  5 IN "UNITS" (X,Y) =   190   67
INITIAL LOCATION FOR VEHICLE  6 IN "UNITS" (X,Y) =    49   31
INITIAL LOCATION FOR VEHICLE  7 IN "UNITS" (X,Y) =    51    5
INITIAL LOCATION FOR VEHICLE  8 IN "UNITS" (X,Y) =   183  249
INITIAL LOCATION FOR VEHICLE  9 IN "UNITS" (X,Y) =     1   69
INITIAL LOCATION FOR VEHICLE 10 IN "UNITS" (X,Y) =   205  153
INITIAL LOCATION FOR VEHICLE 11 IN "UNITS" (X,Y) =    94   65
INITIAL LOCATION FOR VEHICLE 12 IN "UNITS" (X,Y) =   160  265
1        SYSTEM STATUS AT TIME      0.0    FOR RUN      1
0               ACTIVE DEMAND LIST
  DN    OX   OY    DX   DY PC PRTY    DTIME       DPTIME  DN    OX   OY    DX   DY
   1  126  113   252  139  1   1       0.0         0.0     9  208   54     1  15[illegible]
  10  213   29   158   74  1   1       0.0         0.0    11  252   27    87   6[illegible]
   6  174   55   221  145  1   1       0.0         0.0     8  186   83   271  2[illegible]
   3   49   74    95  136  1   1       0.0         0.0     7   72  142   189   35
   4  189  159    84  145  1   1       0.0         0.0     2   67   56   273  133
   5  141  295   218   26  1   1       0.0         0.0
0  VEHICLES AND TOUR LISTS.
  DN    TX    TY  P  TIME     CONST       DN    TX    TY  P  TIME     CONST

0VEHICLE   1 LAST POSITHON X  154, Y  154 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
   1   126   113    1373     2.38     7.62      1   252   139      -1     8.94
0VEHICLE   2 LAST POSITION X  111, Y  221 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
0VEHICLE   3 LAST POSITION X  275, Y  155 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
0VEHICLE   4 LAST POSITION X  263, Y   40 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
   9   208    54    1843     2.72     2.22     11   252    27    1958     5.53
  10   158    74      -1    11.47     2.84     11    87    60      -1    15.28
0VEHICLE   5 LAST POSITION X  190, Y   67 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
   6   174    55    1673     0.96     6.95      8   186    83    1788     2.78
   8   271   202      -1    10.57     8.21
0VEHICLE   6 LAST POSITION X   49, Y   31 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
   3    49    74    1493     2.06     4.23      7    72   142    1733     5.77
   7   189    35      -1    14.14     8.37
0VEHICLE   7 LAST POSITION X   51, Y    5 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
0VEHICLE   8 LAST POSITION X  183, Y  249 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
0VEHICLE   9 LAST POSITION X    1, Y   69 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
0VEHICLE  10 LAST POSITION X  205, Y  153 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
   4   189   159    1553     0.82     7.54      4    84   145      -1     6.38
0VEHICLE  11 LAST POSITION X   94, Y   65 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
   2    67    56    1433     1.37     8.63      2   273   133      -1    12.30
0VEHICLE  12 LAST POSITION X  160, Y  265 AT     0.0 , CURRENT CONTENTS
 AVERAGE EARLINESS  0.0    , AVERAGE LATENESS  0.0    , CURRENT TOUR FOLLO
   5   141   295    1613     1.70     8.30      5   218    26      -1    15.49
1 INTERMEDIATE I/O AT TIME =      15.000 FOR RUN      1
```

```
COMPOSITE VEHICLE AVERAGE CONTENTS=  0.56 AND PER CENT TIME EMPTY= 33.1
  40 DEMANDS REPRESENTING    40 PASSENGERS HAVE OCCURRED WITH AN AVERAG
  24 PICKUPS AND    10 DELIVERIES HAVE BEEN MADE, LEAVING    30 DEMANDS
THE MEAN OF THE INDIVIDUAL LEVELS OF SERVICE IS  0.0  WITH A VARIANCE O
NO DEMANDS BEING OBSERVED HAVE REACHED THEIR DESTINATIONS
1 INTERMEDIATE I/O AT TIME =      30.000 FOR RUN     1

COMPOSITE VEHICLE AVERAGE CONTENTS=  0.96 AND PER CENT TIME EMPTY= 27.1
  69 DEMANDS REPRESENTING    69 PASSENGERS HAVE OCCURRED WITH AN AVERAG
  49 PICKUPS AND    30 DELIVERIES HAVE BEEN MADE, LEAVING    39 DEMANDS
THE MEAN OF THE INDIVIDUAL LEVELS OF SERVICE IS  0.0  WITH A VARIANCE O
NO DEMANDS BEING OBSERVED HAVE REACHED THEIR DESTINATIONS
1 INTERMEDIATE I/O AT TIME =      45.000 FOR RUN     1

COMPOSITE VEHICLE AVERAGE CONTENTS=  1.17 AND PER CENT TIME EMPTY= 21.9
  85 DEMANDS REPRESENTING    85 PASSENGERS HAVE OCCURRED WITH AN AVERAG
  75 PICKUPS AND    52 DELIVERIES HAVE BEEN MADE, LEAVING    33 DEMANDS
THE MEAN OF THE INDIVIDUAL LEVELS OF SERVICE IS  0.0  WITH A VARIANCE O
NO DEMANDS BEING OBSERVED HAVE REACHED THEIR DESTINATIONS
1 INTERMEDIATE I/O AT TIME =      60.000 FOR RUN     1

COMPOSITE VEHICLE AVERAGE CONTENTS=  1.30 AND PER CENT TIME EMPTY= 17.9
 109 DEMANDS REPRESENTING   109 PASSENGERS HAVE OCCURRED WITH AN AVERAG
  96 PICKUPS AND    76 DELIVERIES HAVE BEEN MADE, LEAVING    33 DEMANDS
THE MEAN OF THE INDIVIDUAL LEVELS OF SERVICE IS  2.96 WITH A VARIANCE O
THE OVERALL WEIGHTED LEVEL OF SERVICE IS  2.17


STATISTICS FOR DEMANDS IN PRIORITY CLASS    1 :
CCOMPOSITE STATISTICS FOR     9 DEMANDS AND     9 PASSENGERS:
THE WEIGHTED LEVEL OF SERVICE IS  2.17
0                                              BY DEMAND
                                 WAITING TIME  TRAVEL TIME   TOTAL TIME
MEAN                                 7.747        9.729        17.476
VARIANCE                             9.192       17.658        19.769
NORMALIZED MEAN                      0.775        0.610         0.696
WEIGHTED NORMALIZED MEAN             0.775        0.635         0.701
NO. OF CONSTRAINT VIOLATIONS         2            0             0
NORMALIZED VIOLATION TIME            0.048        0.0           0.0
MAXIMUM                             13.235       16.785        25.178
MINIMUM                              2.535        3.270        10.336
NORMALIZED MAXIMUM


    R; T=0.21/1.58 17.59.58
    >LOGOUT X
    T=0.24/2.04 18.00.14
    CP ENTERED.

    >LOGOUT X
     SHIFT CONNECT     TOTAL     VIRTUAL
       1   0:02:38   0:31.92   0:00.21
       2   0:00:24   0:00.16   0:00.02
    LOGOUT AT 18.00.24 ON 12/07/70

    CP/67 VERSION 2.0-21  11/25/70
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Attachment No. 1 to UMTA Form 1

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Urban Systems Laboratory
Cambridge, Massachusetts

APPENDIX C

W O R K   S T A T E M E N T

DIAL-A-BUS SYSTEM COMPUTER PROGRAMS

June, 1970

1.0 INTRODUCTION

The Urban Mass Transportation Administration (UMTA) has supported a program to investigate the viability of dynamically responsive, demand-activated transportation systems in general and the Dial-A-Bus concept in particular. Future effort is required to place an operative Dial-A-Bus system in an urban community. Specifically two operational dispatching programs are required and will be developed. The first, the Basic Program, can be used for planning purposes to test and evaluate the requirements and performance of a Dial-A-Bus system for any particular urban setting. The second, the Advanced Program, expands upon the basic program and can be used to operate a Dial-A-Bus system in an urban community. With the Advanced Program, service requests can be entered and the system will dynamically schedule a fleet of vehicles to service those requests. Both the Basic and Advanced Programs will be written using the Fortran IV programming language and implemented to run on the System/360 Model 67 time-sharing computer. For each program, copies of source and object decks and complete listings will be delivered to UMTA.

Section 2 of this document describes the Dial-A-Bus concept and the motivation for a Dial-A-Bus type service. Section 3 is a work description for both programs.

2.0 BACKGROUND

2.1 System Operation

The easiest way to describe the Dial-A-Bus operation is to trace through a typical transaction. A person wishing to make a trip will register his request by a telephone call to central dispatching headquarters. (Advanced systems will also be able to handle the patron who wishes to hail a vehicle on the street. The driver who picks him up will register his trip request by radio, and then rendezvous with the vehicle assigned to carry him to his destination.) The operator who answers the phone will request the patron's origin and destination. (In advanced systems, partons who desire will be able to dial this information directly into the computer - from any Touch-Tone phone.) While he waits, the operator will type this information into the computer just as an airline reservation clerk today interrogates the computer system to see if space is available on a given flight.

The computer will be programmed to implement specified decision criteria. It will also contain a record of current vehicle locations and of all trips currently awaiting service. Having received the latest request for service, it will search its records for vehicles (a) that are near the origin and moving in the general direction of the trip to be served, and (b) that are currently idle (if any). It will also review a wide variety of other information - for example, the straight-line speeds toward their destinations that the passengers currently on each vehicle have made since telephoning their requests, and the likely impact upon their average trip speeds that a new diversion would impose upon them, considering probable congestion characteristics at this time of day.

Based on this information and a series of decision rules, the computer will insert the new trip in a manner to minimize the inconvenience of other passengers and maximize service to the new customer.

When a vehicle is selected, the computer will print out the vehicle identification number, the expected time of pick up (within a narrow range: e.g., seven to eleven minutes), and the expected time of arrival at the customer's destination (likewise within a narrow range). The operator will read this information to the waiting customer. The whole transaction will have taken about a minute.

The customer will be expected to watch from his window at the anticipated time of pickup. When the bus appears, he will be expected to emerge within a specified period (e.g., thirty seconds).

The driver will receive his instruction either from a human operator (via two-way radio) or directly from the computer. In the former case, the operator will be sitting at a computer terminal, and will receive printouts as needed stating each vehicle's next stop. In either case, the driver will give notification each time he reaches a stop. While the passenger pickup or drop-off is taking place, the driver will be assigned his next stop.

Typically, the new patron will find several patrons already on the bus when he boards. (The computer will avoid filling any vehicle beyond its seat capacity except when the total system is overloaded, (as during snowstorms). After a journey which may include several stops required to serve other patrons, he will arrive at this destination by the time the computer originally guaranteed.

2.2 The Motivation for a Dial-A-Bus Service

Increasingly, our urban land use patterns and transportation systems are designed mainly for the nation's auto-owning and auto-driving majority. Large portions of the American population, however, find it difficult to get around by automobile.

These include the poor, those too young or old to drive, and - much of the time - even such groups as the housewives in one-car families (only one-quarter of American families own two or more cars). Despite popular stereotypes, there are barely more multiple-car families than no-car families.

Those who have not achieved full"auto-mobility" are a substantial group indeed. In 1964, 12.9 million U. S. households (23 percent) did not own a car. Roughly half of these were in the central cities of SMSA's, where they consituted thiry-five percent of all households. Nearly one-quarter (24 percent) of all Americans over the age of twenty were not licensed to drive.

Looking ahead, poverty will become an ever less significant obstacle to auto ownership. The proportion of aged people will grow, however, as will the potential market for services geared to the mobility needs of those too young to be licensed. By 1980, it is estimated that 100 million Americans will either be under eighteen or over sixty-five. There are powerful safety arguments, moreover, for restricting the driving privilege somewhat more rigorously than we have to date. At the moment, legislatures and courts feel that they have to let virtually any adult drive, because to be unlicensed is in a vital sense to be crippled.

People who do not have access to an automobile must rely on some form of public transportation. The decline in available transit services has resulted in a significant decrease in travel opportunities to a large segment of the public. Whereas the overall mobility of the American urban dweller has increased dramatically over the past several decades, there is an alarming disparity between those who can get around by driving and those who cannot.

The central problem faced by nondrivers and by the transit industry is the increasing dispersion of trip-generating activities. This dispersion is a natural consequence of automobile dominance which makes getting around on foot and serving travel demand by conventional transit ever more difficult.

Some contend that the answer is a radical improvement in fixed-route transit service that will reverse the trend toward urban decentralization and will satisfy the amenity expectations of the contemporary American public. This hope seems illusory. The forces making for urban decentralization are overwhelming. They range from the American desire for freestanding one-family homes, to the need of modern shopping and employment centers with adjacent parking, to the physical design demands of modern industrial technologies, to the advertising expenditures of the automobile industry.

In general, then, it is maintained that the future of transit will depend on its ability to adapt to urban decentralization rather than to challenge it (i.e., to incorporate characteristics similar to automobile travel). Already, there are few metropolitan areas in which as many as ten percent of all trips are downtown-oriented: this is both an unusually peaked and a declining trip category. The fact that transit is so heavily oriented toward such trips accounts largely for the decline of transit and for the extreme severity of its peaking problem.

Few travel corridors in the present era have demand densities adequate to support rail transit. Conventional bus service has far greater flexibility than rail transit, but it too requires corridor densities that are increasingly rare. A typical estimate is that, to break even, conventional bus service requires 100 demands per square mile per hour. For these demands to be realized, they must be to points that are served by the predetermined bus route. Each potential patron must be prepared to endure an outdoor wait at the busstop and most will have to walk at either end of the trip.

The final existing mode of "transit" service is the taxi. It can prosper with demand densities (to dispersed points) of as low as five per square mile per hour, and it offers door-to-door service on demand. These advantages are offset, however, by very high fares and frequent long delays between the communication of a demand and a pickup. These fare levels are made necessary by the fact that each taxi normally handles only one trip at a time. The capacity constraint severely limits the ability of taxi fleets to adjust ot demand variations. In consequence, long delays are common during periods when demand is heavy.

In view, then, of the nature of projected transportation needs and the economic and operational drawbacks of existings modes of public transportation, what appears to be necessary is a transportation system that provides the door-to-door charcteristics of taxi service in a more dynamically responsive way than current taxi operations. In addition, such a system should be able to operate efficiently and economically in low-density environments, perhaps of the order of twenty demands per square mile per hour. The Dial-A-Bus system is designed to provide such a service, and hence is considered to be a critical addition to the spectrum of public transportation.

Research has shown that:

1. Dial-A-Bus can operate economically at demand levels substantially lower than current fixed-route services.

2. Dial-A-Bus can supply an effective dynamically responsive transportation service comparable to taxi operation, but at much lower cost.

3. The computer and communications technology necessary to support Dial-A-Bus exists. A system design has been performed and has demonstrated the technological feasibility and economic viability of the Dial-A-Bus concept.

Previous Dial-A-Bus research has focused in several areas, specifically: 1) the feasibility design of prototype Dial-A-Bus systems, 2) cost and demand estimates for Dial-A-Bus service, 3) evaluation of various alternative systems, 4) social, political, and institutional impacts of Dial-A-Bus, and 5) formulation of routing algorithms - the means by which pickup and delivery decisions are made.

The Dial-A-Bus concept has been judged to be viable from all the above standpoints. The next step is to develop operational Dial-A-Bus systems. Proposed work to accomplish this is described in the following section.

3.0 WORK DESCRIPTION

It is proposed to develop two related operational computer dispatching programs for use in the Dial-A-Bus environment. These programs are as follows:

1. <u>The Basic Program</u>

   This program will serve as a planning tool. It will be used to pretest Dial-A-Bus in a particular enviroment, allowing tailoring of the Dial-A-Bus system to fit into the given condition in an efficient fashion.

2. <u>The Advanced Program</u>

   This program, which may be considered as an enhancement of the Basic Program, can be used to operate a Dial-A-Bus system in a given community. The Advanced Program will accept a stream of actual customer demands, make routing decisions and output messages to the appropriate vehicles giving their destinations. The Basic Program can therefore be used to optimize Dial-A-Bus for local conditions and subsequently, the Advanced Program can be used to operate and control an actual Dial-A-Bus system.

Both programs in operational form will be delivered to UMTA in the form of source decks, object decks, and complete connected source listings. The programs will be on the IBM System 360 Model 67 under the CP/CMS operating system, a standard supported IBM system. The maximum size of the virtual machine required to run either program is 512,000 bytes.

THE BASIC PROGRAM

External Characteristics

This program is designed so that a planner can tailor Dial-A-Bus to a particular urban environment. More specifically, the Basic Program allows the planner to set various conditions and study the productivity and performance of Dial-A-Ride under various operating strategies. For example, the following external parameters can be set.

1. Area size

2. Demand level as funtion of time

3. Distribution of demands over the service area

4. Mean vehicle velocity between stops

5. Stop time distribution

In addition, various operating strategies can be experimental parameters such as:

1. Number of vehicles

2. Vehicle capacity

3. Nature of service (e.g., many-to-one versus many-to-many service)

4. Maximum allowable waiting times and travel times

5. Heuristic function used to select best vehicle for a given demand

6. Length of test

Given these external and operational parameters, the Basic System will internally generate passenger demands at random intervals at point coordinates within the service area and assign the demands to vehicles in accord with the decision rules input by the planner. When the test is complete, statistics relating to system performance are output.

Typical output statistics include:

1. Mean level of service (ratio of the average service time, i.e., waiting time plus travel time, to direct driving time)

2. Vehicle productivity in passenger trips per vehicle hour

3. Mean vehicle occupancy

4. Maximum waiting time

The planner would then vary his input in his search for an optimal Dial-A-Bus configuration for the particular environment in question.

The Heuristic Routing Algorithm

The Basic Program will utilize the most promising routing techniques. Past research has demonstrated that classical optimization techniques are not fruitful but rather that heuristic assignment algorithms are the appropriate mechanism for an operational real-time Dial-A-Bus environment. The basic heuristic to be used is described below.

Each vehicle has a number of passengers and some users waiting for service assigned to it. At all times the computer maintains provisional future routes for all vehicles which provide for the service of all outstanding customers. Associated with each stop on a vehicle's provisional route are latest arrival times which will satisfy the waiting, travel and total service guarantees of all users. Slacks representing permissible deviations from the direct route are computed from these constraints. When a new service request is received, these slacks are used to determine whether particular placings of the new origin and destination will violate any of the user's guarantees for all passengers assigned to that vehicle, and the new user.

In the assignment of a new demand, all possible placings of the origin and destination are examined for each vehicle. The actual assignment is chosen by evaluating selection criterion for all feasible assignments. The selection criterion tries to maximize the satisfaction of both present and future users by minimizing their expected service times. Consider just the current users, a possible selection criterion is:

$$\text{Minimize } Z_1 = N_1 e_1 + N_2 e_2 + ST$$

where N_1 is the number of customer deliveries after the insertion of the origin stop for the new demand (see Figure 1). N_2 is the number of customer deliveries after the insertion of the destination stop for the new demand. e_1 is the vehicle detour time due to the insertion of the origin of the demand. e_2 is the vehicle detour time due to the insertion of the destination of the new demand. ST is the service time of the new customer for this insertion.

Then Z_1 measures the time which will be lost by all passengers currently on the system if the new demand is assigned in this manner.

Similarly considering just the future demands, a possible selection criterion is:

$$\text{Minimize } Z_2 = e_1 + e_2$$

This frees all vehicles as soon as possible thus enabling them to service new requests.

Combining Z_1 and Z_2 produced the following criterion:

$$\text{Minimize } Z_3 = (N_1 + 1)\ e_1 + (N_2 + 1)\ e_2 + ST$$

Heuristics of the above types have been shown to be effective for Dial-A-Bus. The Basic Program must be designed to allow these heuristics and variations to be structured. A typical use of the Basic Program would be to compare Z_1, Z_2, and Z_3 for a particular operating enviroment. Example results are shown in Figure 2. Using results of this type, the planner can make judgments as to which selection criterion should be used, how many vehicles are required to provide a given level of service, etc. Thus, complete pretailoring of Dial-A-Bus is accomplished with the Basic Program.

THE ADVANCED PROGRAM

While the Basic Program will allow the planning to Dial-A-Bus system, the Advanced Program will operate a Dial-A-Bus system. The heart of both the Basic and Advanced Programs are the decision-making rules for assigning demands to vehicles. However, the two programs differ markedly in several ways. In the Basic Program, demands are generated internally (random in space and time). In the Advanced Program, demands are input externally. That is, actual demands in terms of customer names, street addresses, etc., serve as the input to the Advanced Program. This implies that a transformation of street addresses into geographical coordinates must take place (so that routing decisions can be made). Thus, for the Advanced Program to be

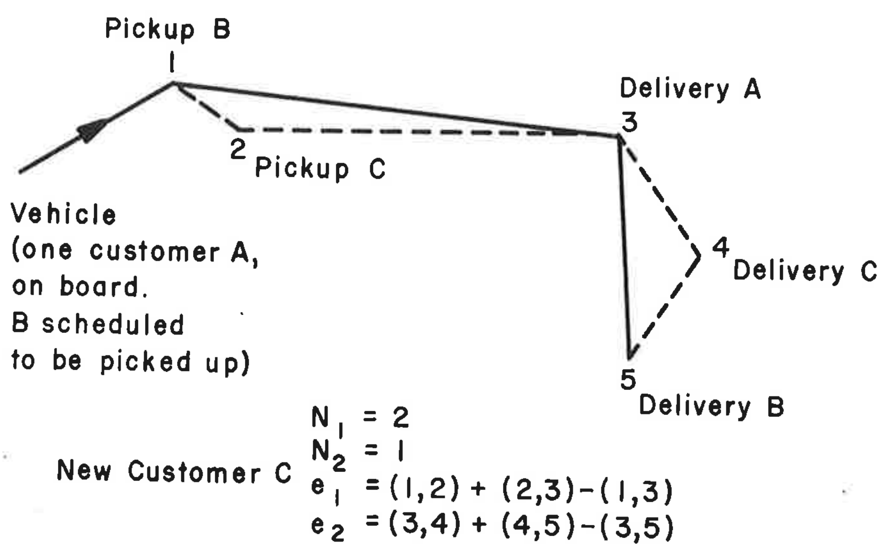

Figure 1. One Possible Insertion for C, New Demand

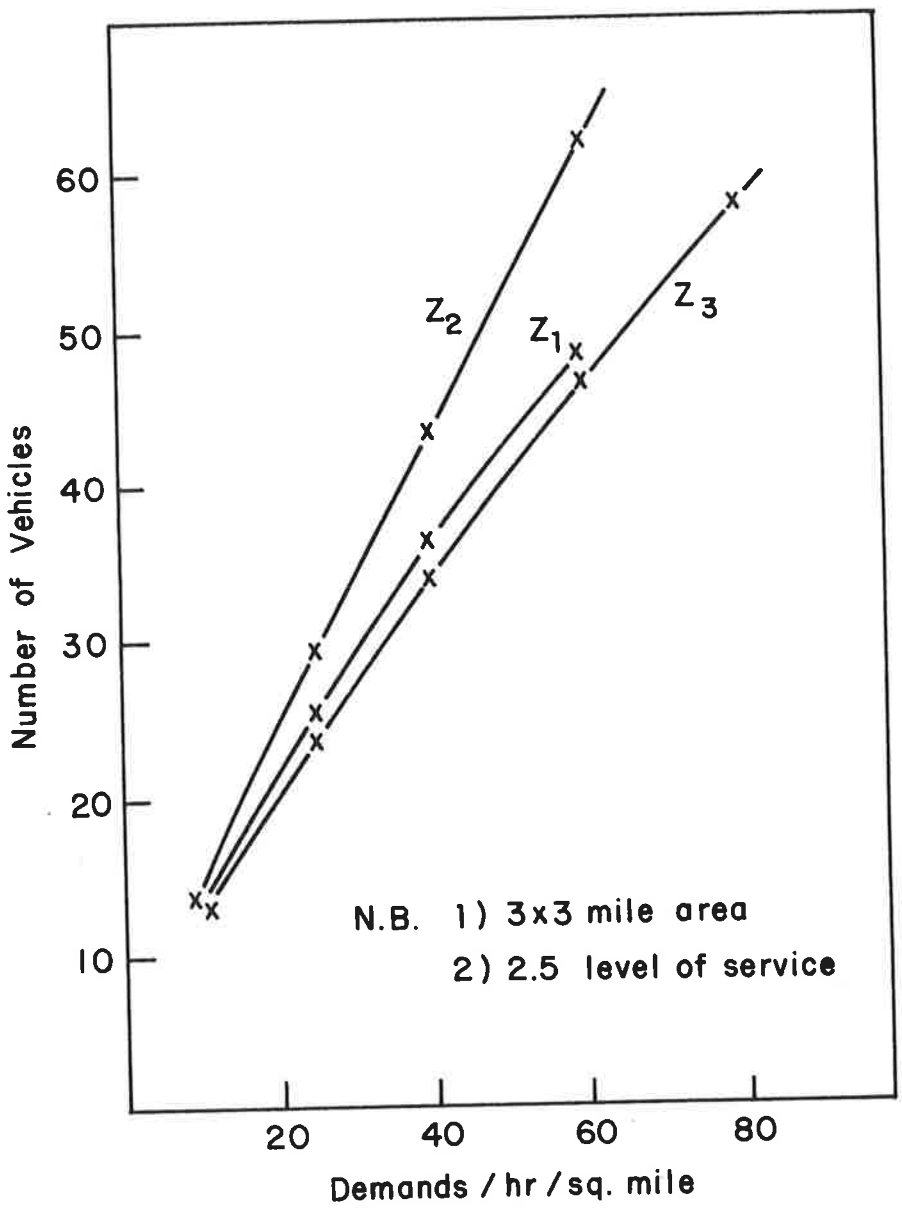

Figure 2. Effect of Selection Criterion on Heuristic Performance

operational for a given area, a transformation table must be constructed and may be considered as part of the site dependent data for the program. In addition, in using the Advanced Program, the user should be able to retrieve the next assignment for a given vehicle at any point in time. (This is of course not required for the Basic Program.)

Given these capabilities, one can use the Advanced Program for operating a Dial-A-Bus System. System operation is shown schematically in Figure 3.

In effect, the Advanced Program is the Basic Program with certain additional input-output requirements. However, to insure its usability as an operational system, several extra added features are required. Among these are:

1. Restart capability

2. Cancellation of a service request

3. Handling of more passengers at a stop than expected

4. Vehicle breakdown procedure (includes re-assignment of passengers)

5. Detection of late vehicles (both for internal computation purposes and breakdown suspicion)

6. Priority classes

Information Flows in The Advanced Program

Specification of the various information flows as input to and output from the operational Advanced Program is summarized below.

Information transmitted by the customer to the operator will typically include:

1. Self identification (e.g., name or identifier code)

2. Origin location

3. Destination location

4. Number of passengers

Information transmitted to the customer by the operator (from the Advanced Program) will typically include:

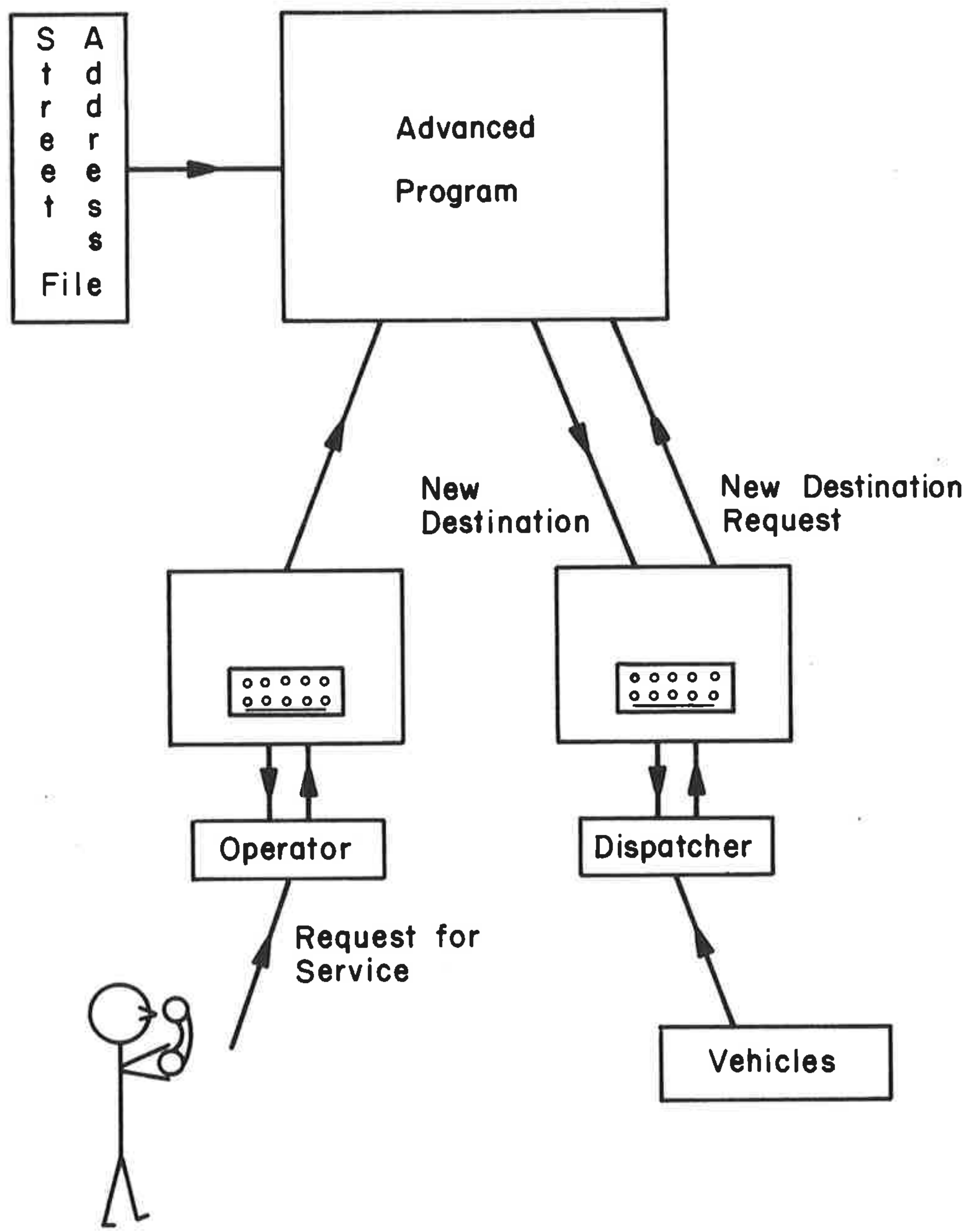

Figure 3. Advanced Program Operation

1. Acknowledgment

2. Estimated collection time

3. Vehicle identification number

Typically, information sent to a vehicle by the dispatcher will include:

1. Location of its next stop

2. Number of passengers to be collected or discharged

3. Fare(s) (if stop is a pickup point and fare is to be collected)

4. Logical vehicle number to be displayed

Typical messages from a vehicle are:

1. Message acknowledgment

2. Repeat last transmission

3. Vehicle arrived its assigned stop, request next stop information

4. Vehicle emergency

Implementation of The Advanced Program for A Demonstration Project

The Advanced Program has been designed in a flexible, modular manner so it can operate different Dial-A-Bus systems; it is not site specific. Once the street network for an area has been established in the computer, the program can be used.

Since the program is designed to run using time-sharing computer only a portion of the machine need be used for operation of the Dial-A-Bus system. Furthermore because of the communications capabilities possible with a time-sharing machine, the computer can be at any distance from the site of the Dial-A-Bus service.

The Advanced Program is designed to operate on a single computer. Therefore no computer backup is provided if a failure occurs. To insure reliable service to customers, adequate manual backup capabilities should therefore be provided.

SUMMARY

A Basic Program for planning and an Advanced Program for operating will be developed. It is expected that the second effort will grow directly from the first with many routines being common to both. Both programs will operate interactively on a time-sharing computer, specifically, an IBM 5/360/67 under CP/CMS in a 512,000-byte virtual machine.

APPENDIX D

Operating Guidelines for the
Dial-A-Ride Basic and Advanced
Computer Programs

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OPERATING GUIDELINES FOR THE DIAL-A-RIDE BASIC AND ADVANCED COMPUTER PROGRAMS

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OPERATING GUIDELINES FOR THE DIAL-A-BUS BASIC PROGRAM

1.0 INTRODUCTION

The tape contains the Basic DIAL-A-BUS Program developed by the Massachusetts Institute of Technology under contract Mass-MTD-6 sponsored by the Urban Mass Transportation Administration (UMTA). The following documentation includes a tape description, a program description, the loading procedures, and hardware requirements. In addition, comments are made concerning loading commands, CP/CMS variations, and running procedures.

A prerequisite for using the guidelines contained herein is an understanding of the CP-67 time-sharing system and the CMS operating system, as well as familiarity with the DIAL-A-BUS Basic Program Implementation and User's Guide dated July 1970, as prepared by the M.I.T. Urban Systems Laboratory.

2.0 FORMAT AND OPERATION

2.1 Hardware Requirements

The Basic Program, as contained on this tape, is designed to be executable on an IBM system 360 model 67, using Control Program 67 time-sharing system (CP-67) and the Cambridge Monitoring System (CMS). The minimum core requirements are 350 K bytes. In addition, 12 cylinders of disk storage are required. For two terminal operation, two accounts are required (see 3.6).

2.2 Tape Format

The tape is 9-track with a density of 800 BPI and a block size of 805 bytes.

2.3 Tape Files

The tape contains two identical files, the second being a backup file. Each file has both the source and the text versions in alphabetical order.

2.4 Loading Procedures

The first file on the tape contains both the source and the text versions. To load the first file onto the disk, use the command

1. TAPE LOAD 1

To load and execute the Basic Program from disk in the non-graphic mode issue the command

2.A. RUN NOARDS

If the graphic mode is supported and the ARDS sofrware is contained in the file GPACK, use the command

2.B. RUN ARDS

The above commands to load the program from tape to disk and from disk to core should be sufficient to fully operate the program. However, care should be given to variations in different CP/CMS installations regarding operating procedures (see section 3).

2.5 Source Listing

To obtain a source listing of the program, there is an exec file called BASLST contained in each tape file. Issuing the command

BASLST OFFLINE PRINT

will give the Basic Program listing at an offline printer.

3.0 <u>COMMENTS</u>

3.1 ARDS Software

The ARDS software subroutines necessary to support the graphic mode of this program are not contained in the tape files because they are proprietary and must be obtained from the vendor. Therefore, the ARDS software has been dummied out. The entry points and subroutine names are contained in the subroutine IBM65. If the ARDS software is supported and given the filename GPACK, and if the proper RUN command is issued, the subroutine IBM65 is not loaded by the RUN exec file.

3.2 LOAD and USE Commands

The RUN exec file contains the LOAD and USE commands. Under the particular CMS operating system used, each file containing a subroutine, an entry point, a main program or block data had to be in a LOAD or a USE command. However, certain modified CMS operating systems eliminate the need for specifying called subroutines in the USE command, since the file is automatically searched for unresolved entry points for the programs contained in the LOAD command. In this case, the USE command should never be employed or else redundant program loading may occur that will overflow the computer core and prevent execution of the program. Reference should be made to the loading procedures employed at the particular computer installation that is used.

3.3 RUN Exec File

The RUN exec file loads the necessary text version files from disk into core storage, provides the linkage, and starts execution of the program.

3.4 MAIN and BLOCK DATA

There are three files, MAIN, BLOCK, and TUFACE, the first is the main program, the other two being block data files. Under the Standard IBM CMS operating system, each must be in a load or a use command.

3.5 Files

Each subroutine in the program is in a separate file. A combining of files could reduce core size required for operation, however, for ease in program modification, separate files are desirable.

OPERATING GUIDELINES FOR THE DIAL-A-BUS ADVANCED PROGRAM

1.0 INTRODUCTION

The tape you have received contains the Advanced DIAL-A-BUS Program developed by the Massachusetts Institute of Technology under contract Mass-MTD-6 sponsored by the Urban Mass Transportation Administration (UMTA). The following documentation includes a tape description, a program description, the loading procedures, and hardware requirements. In addition, comments are made concerning loading commands, CP/CMS variations, and running procedures.

A prerequisite for using the guidelines contained herein is an understanding of the CP-67 time-sharing system and the CMS operating system, as well as familiarity with the DIAL-A-BUS Advanced Program Implementation and User's Guide dated July 1970, published by the M.I.T. Urban Systems Laboratory.

2.0 FORMAT AND OPERATION

2.1 Hardware Requirements

The Advanced Program, as contained on this tape, is designed to be executable on an IBM system 360 model 67, using Control Program 67 time-sharing system (CP-67) and the Cambridge Monitoring System (CMS). The minimum core requirements are 350 K bytes. In addition, 12 cylinders of disk are required, and two accounts are necessary for a two terminal operation (see 3.6).

2.2 Tape Format

The tape is 9-track with a density of 800 BPI and a block size of 805 bytes.

2.3 Tape Files

The tape contains two identical files, the second being a backup file. Each file has both the source and text versions in alphabetical order.

2.4 Loading Procedures

The first file on the tape contains both the source and the text versions. To load the first file onto the disk, use the command

1. TAPE LOAD 1

To load and execute the Advanced Program from disk using one terminal, use the command

2.A. RUN ONE NOARDS

If using two terminals (the second being in the sleep mode), use the command

2.B. RUN TWO NOARDS

If the ARDS feature is supported, the ARDS software must be given the filename of GPACK.

The command for running with one ARDS alone, or one ARDS and one teletype are

2.C. RUN ONE ARDS

2.D. RUN TWO ARDS

respectively.

The above commands to load the program from tape to disk and from disk to core should by sufficient to fully operate the program. However, care should be given to variations in different CP/CMS installations regarding operating procedures (see section 3).

2.5 Source Listing

To obtain a source listing of the program, there is an exec file called ADVLST contained in each tape file. Issuing the command

ADVLST OFFLINE PRINT

will give the Advanced Program listing at an offline printer.

3.0 COMMENTS

3.1 ARDS Software

The ARDS software subroutines necessary to support the graphic mode of this program are not contained in the tape because they are proprietary and must be obtained from the vendor. Therefore, the ARDS software has been dummied out. The entry points and subroutine names are contained in the subroutine DUMMY. If the ARDS software is supported and given the filename GPACK, and if the proper RUN command is issued, the subroutine DUMMY is not loaded by the RUN exec file.

3.2 LOAD and USE Commands

The RUN exec file contains the LOAD and USE commands. Under the particular CMS operating system used, each file containing a subroutine, an entry point, a main program or block data had to be in a LOAD or a USE command. However, certain modified CMS operating systems eliminate the need for specifying called subroutines in the USE command, since the file is automatically searched for unresolved entry points for the programs contained in the LOAD command. In this case, the USE command should never be employed or else redundant program loading may occur that will overflow the computer core and prevent execution of the program. Reference should be made to the loading procedures employed at the particular computer installation that is used.

3.3 RUN Exec File

The RUN exec file loads the necessary text version files from disk into core storage, provides the linkage, and starts execution of the program. Also contained in the RUN exec file are the initial bus locations for the seven vehicles.

3.4 MAIN and BLOCK DATA

There are three files, MAIN, BLOCK, and TUFACE, the first is the main program, the other two being block data files. Under the Standard IBM CMS operating system, each must be in a load or a use command.

3.5 Files

Each subroutine in the program is in a separate file. Combining files could reduce core size required for operation.

3.6 One and Two Terminal Operation

In order that the vehicle dispatching messages can be obtained using one terminal, the subroutines RESCHD and QUIET contain the primary account name TOYE in line 530 of QUIET and lines 500, 520, 540, 590 of RESCHD. When using two terminals RESCHD2 and QUIET2 are loaded. These two subroutines have the secondary account name TOYE in the above mentioned lines which corresponds to the second terminal (placed in the sleep mode). In order to continue in this manner, those four subroutines must be modified to contain the new primary and secondary account names in place of the old account names, TOYE and TOY2, and the routines recompiled.