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16. Abstract

This report is the user's manual for a software package called "RAMBO" (Ramp Adaptive Metering Bottleneck Optimization). RAMBO is the end product of research conducted within SPR research project 1232 entitled "Urban Highway Operations Research and Implementation." It was developed by the Texas Transportation Institute for the Texas Department of Transportation as a practical ramp metering system, primarily for Texas applications. RAMBO consists of two complimentary programs RAMBO I and RAMBO II.

RAMBO I employs interactive graphic screens to assist the traffic engineer in evaluating local ramp traffic conditions. It generates ramp metering plans based on the TxDOT ramp meter specification TxDOT-550-80-950-02 dated December 1991. It also generates Transition Point Patterns for each metering level.

RAMBO II is a system ramp metering package that evaluates ramp metering plans based on forecasted traffic conditions along an extended section of freeway containing up to 12 metered entrance ramps and 12 exit ramps.

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RAMP ADAPTIVE METERING BOTTLENECK OPTIMIZATION (RAMBO) USER'S MANUAL

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IMPLEMENTATION STATEMENT

The Texas Department of Transportation is in the process of implementing freeway entrance ramp metering along several freeways within the state. The ramp metering systems are designed to minimize traffic congestion and to improve air quality and traffic safety. This report is the user's manual for ramp metering software developed by the Texas Transportation Institute and is provided to assist those traffic engineers responsible for successful operation of the new ramp metering systems in Texas.

The total software package, named RAMBO, can perform capacity analysis of the freeway system, assess projected metering operation, and assist in developing optimal ramp metering plans for either local ramp metering operations (using RAMBO I) or system ramp metering operations (using RAMBO II). RAMBO II can translate system-based results into local metering control parameters that can be downloaded into the local ramp meters if some minor modifications are made to the current ramp meter specifications.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT), or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge of the project was Carroll J. Messer, P.E. # 31409.

ACKNOWLEDGEMENTS

RAMBO was developed with the active cooperation of all the authors listed in this report. Michael E. Thomadakis was primarily responsible for the development of the RAMBO I code. Hassan A. Charara was primarily responsible for the development of the RAMBO II code. Kevin D. Tyer prepared several real-world data sets for Houston freeways and tested RAMBO on them. His assistance is gratefully acknowledged. Carroll J. Messer was the engineer in charge of this research task. He formulated the traffic models used and guided the team members throughout the duration of the work. Thomas Urbanik II was the principal investigator of the overall 1232 project. Authors acknowledge the contributions of E.C.P. Chang, Su-Hua Wang, Wei Huang, and Allen Li for their earlier work on System Interface for Freeway Ramp Metering. Numerous other research staff and computer programmers were also involved in the development of the software for RAMBO and their contributions are acknowledged.

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SUMMARY

This report is the user's manual for a software package developed by the Texas Transportation Institute for the Texas Department of Transportation. The suite of two complementary and fully compatible programs is called RAMBO (Ramp Adaptive Metering Bottleneck Optimization). Both RAMBO I and RAMBO II have extensive interactive graphic screens. They are the end products of several years of research within SPR research project 1232 entitled "Urban Highway Operations Research and Implementation."

RAMBO I is a software tool designed to assist the Texas traffic engineer who is responsible for developing ramp metering plans using the TxDOT ramp meter specification TxDOT-550-80-950-02 dated December 1991, while operating in the isolated mode, or in local control. This report provides Transition Point Patterns for each metering level and evaluates traffic operations.

RAMBO II likewise develops and evaluates ramp metering plans based on forecasted traffic conditions along an extended section of freeway containing up to 12 metered entrance ramps and 12 exit ramps operating either in the system mode, or in a hierarchically distributed system having real-time local control with systems-based metering objectives.

1. INTRODUCTION

PURPOSE AND SCOPE

Researchers developed the Ramp Adaptive Metering Bottleneck Optimization (RAMBO) software as an operational analysis package for pre-implementation studies of ramp metering. They designed this microcomputer-based package to assist traffic engineers in developing freeway control strategies and ramp metering plans. The RAMBO software was developed specifically for Texas urban freeways using Texas Department of Transportation's (TxDOT) specifications for ramp meters *(1)*. It can serve as an operational analysis tool to generate metering plans for controlled ramps and to optimize a system of ramps. A previous research report described advanced ramp metering strategies and identified the data structures, control variables, and operational algorithms of an overall ramp metering design concept *(2,3)*. The earlier reports include the complete mathematical formulation of the systems ramp metering problem which provides the technical information behind the RAMBO software. The scope of this user's manual is limited to the operations of the RAMBO analysis package for the off-line application of ramp metering using the TxDOT specification(s).

This first version of the RAMBO software consists of two individual programs: RAMBO I and RAMBO II. The programs have their own distinct functions and capabilities and are designed to evaluate local or system metering respectively. RAMBO I is the *Local* Ramp Adaptive Metering and Bottleneck Optimization program which generates the metering plans for isolated ramps or a series of ramps operating in the isolated mode. RAMBO II is the *System* Ramp Adaptive Metering and Bottleneck Optimization program which optimizes the traffic flow along a freeway system. This systems-based program uses linear programming to develop optimal ramp metering rates and directly estimates the operational performance for both individual entrance ramps and the entire freeway.

OBJECTIVE OF THE USER'S MANUAL

The objective of the user's manual is to provide the user with information essential to the operation of RAMBO I and II. The authors anticipate that the manual will be used by engineers and technicians responsible for developing ramp metering plans for urban freeways in Texas using the RAMBO software. The various capabilities and functions of the RAMBO

software are documented in the manual. It is intended as a guide for the RAMBO I and II user, but it does not provide specific guidelines for developing ramp metering strategies and plans. These guidelines may follow as field experience is gained with the software.

SYSTEM REQUIREMENTS

The complete system requirements for using the RAMBO software are the following:

- DOS 3.0 or higher;
- 640 K of RAM with 500 K available for the program;
- Files set equal to 15 or higher in the config.sys file;
- The ansi.sys device driver loaded; and
- One megabyte of disk space available for storing the program.

ORGANIZATION OF THE USER'S MANUAL

The body of the user's manual is divided into two basic parts. Chapter 2 provides the user's guide to the RAMBO I program. Chapter 3 documents the RAMBO II system.

2. RAMBO I

This chapter is the user's manual for RAMBO I, the Local Ramp Adaptive Metering and Bottleneck Optimization program. The intended audience includes mainly traffic engineers and technicians who will use RAMBO I as a tool to generate and optimize metering plans for metered ramps. Technical information and documentation about the RAMBO I computer program itself is not included in this chapter.

OBJECTIVE

The main objective of RAMBO I is to assist traffic engineers or technicians generate and optimize metering plans for metered ramps in the local (isolated) mode of operation. RAMBO I is designed specifically for the TxDOT ramp meter specification TxDOT-550-80-950-02, dated December 1991 *(1)*. RAMBO I utilizes freeway traffic flow information which is local to the metered ramp. The user needs to enter all pieces of the local information for a ramp only once. RAMBO I then immediately generates up to four metering plans at a time for this ramp. The user may experiment with the input parameters until the desired metered performance levels are attained by the metered ramp.

The user can save the ramp related information and the generated transition point tables on plain ASCII (text) files, called "Ramp Files" for future processing. By convention, a ramp file has extension "`*.RMP`" as in "`MyRamp.RMP`." Alternatively, the user may print input data and generated transition tables on hard-copy devices. If desired, the user may easily retrieve ramp information already stored on a ramp file, experiment with and modify it, and print the results or save it again on a ramp file. Ideally, there should be a different ramp file for each one of the ramps the user desires to meter. For instance, assume there are 20 metered ramps on the metered freeway. The user may prepare up to 20 different ramp files, one for each of the ramps of interest. RAMBO I generates the transition tables for up to four metering plans of a ramp as soon as all necessary input parameters have been entered. RAMBO I then saves the transition point tables along with the input data on the same ramp file. In this way a user may gather together the transition tables of a metered ramp as well as the input information the program had used to generate them in a single text file. Ramp files are stored

as plain ASCII files so the user may access and modify them outside RAMBO I using any available text editor, if this is more convenient.

Subsequent parts of this chapter describe in detail the computer system requirements, the user-to-program interaction, the kind of local information user must enter, the user's experimentation with the program, saving, printing, and the retrieval of the results can be later retrieved.

MS-DOS SOFTWARE COMPONENTS

RAMBO I requires a graphics driver module that comes with Turbo C 2.0. The graphics driver file is dependent on the graphics adapter card with which the computer is equipped. For instance, if the computer has an EGA or VGA type of card, the necessary graphics driver file is called "**EGAVGA.BGI**". RAMBO I is accompanied by all the necessary graphics driver files. Whenever graphical output is requested, RAMBO I automatically detects the type of the card and uses the corresponding graphics driver file. If the user accidentally erases the graphics driver files, then RAMBO I will not be able to generate graphical output and it will produce an appropriate error message on the screen.

The following three standard software utilities are recommended but not absolutely necessary to the operations of RAMBO I.

- **MS-DOS EDIT** command. RAMBO I generates and retrieves standard ASCII text files. A user may access the standard MS-DOS **EDIT** command through RAMBO I, if one wishes to manually create and modify these text files. It is recommended that the MS-DOS **EDIT** command be available and that *its path be provided in the* DOS **PATH** *environment variable*. If the **EDIT** command is not available, the user may not modify the text files from *within* RAMBO I. Outside RAMBO I, the user may use any other available text editor as in normal editing of ASCII text files.

- **MS-DOS MEM** command. It is possible for a user to view the current main memory usage from within RAMBO I. This requires the presence of the MS-DOS **MEM** command. If this command is available, *its path should be provided in the* MS-DOS

PATH *environment variable.* Again, if **MEM** is not available the user will not have the ability while RAMBO I is running to examine its main memory usage.

- **MS-DOS COMMAND** shell. The user may escape temporarily to the MS-DOS command shell from within RAMBO I. This is often very handy when certain common file management operations need to be carried out. For example, a user may need to view a directory listing, copy a file, or even print a text file on a printer. The correct path of the system's **COMMAND.COM** must appear in the **COMSPEC** environment variable. If **COMSPEC** does not contain the path of a valid DOS shell command, then it will not be possible for the user to use DOS commands from within RAMBO I.

All these software components are commonly found in most MS-DOS personal computers. Again, the absence of any of the above components will not affect the operational functionality of RAMBO I.

RAMBO I START-UP PROCESS

RAMBO I is a standalone program and it can be invoked either from the MS-DOS command line, by typing its name:

C:\>RAMBODIR\HP12320

It can also be started from within another program, like RAMBO II, using the appropriate option command key. A user should consult Chapter 3 for information regarding the operations of RAMBO II, and for more information about how to call RAMBO I from RAMBO II.

PRINCIPLES OF OPERATION

This section describes the basic principles of operation of RAMBO I, including the necessary input and the output generated for each metered ramp. The interested reader is referred to Research Report 1232-23 *(2)* and the references therein for additional technical

information on local and system ramp metering. For definitions of concepts and specifications on ramp metering, the reader is referred to the Ramp Meter Signal Controller specification *(1)* of the Texas Department of Transportation.

RAMBO I computes up to four Metering Plans based on the selected freeway capacity downstream of the metered ramp. The target (setpoint) capacity may reflect the actual capacity of the downstream freeway section, a desired level of service rate, or system considerations. Each metering plan has its own occupancy-based transition point pattern. The user must enter pertinent information regarding the metered ramp and RAMBO I will automatically generate the transition point pattern tables for this ramp.

DATA REQUIREMENTS

The user must supply two pieces of data so that RAMBO I can generate the transition point table for the ramp:

Freeway section traffic parameters, and
Signal timing table data of the ramp meter.

As soon as these data are available, RAMBO I will automatically compute the transition point table containing the metering plans for the ramp. RAMBO I can save the freeway section parameters and the signal timing table data, along with the generated transition point table for a ramp on the same ramp data file. Ramp data files are plain text files which a user may edit independently of RAMBO I using any text editor. From within RAMBO I a user may invoke the standard MS-DOS editor `EDIT` command, if available.

USER-TO-PROGRAM INTERACTION

RAMBO I is a user-friendly, standalone program which communicates interactively with the user. It is standalone because it does not need any other software like MS-Windows to create its user interface. The user-to-program interaction is based on simple menu selections, graphics output, and interactive data entry-display forms.

RAMBO I presents the user with information on the screen which is enclosed inside rectangular boxes, commonly known as windows. Each window has a unique title sitting in the middle of its top edge. The title clearly identifies the intended function of the window. There are three types of RAMBO I interaction items which appear inside windows: menus, graphic plots, and interactive data-entry screens.

Menus

A menu is a list of options shown on the screen inside a menu screen. In RAMBO I, each menu item is associated with a command key. When a user presses a command key RAMBO I immediately executes the associated function. RAMBO I uses the following command keys in various operations:

- a function key pressed by itself: from F1 to F10;
- a function key pressed with the <Shift> key: <Shift> F1 to <Shift> F10;
- a function key pressed with the <Ctrl> key: <Ctrl> F1 to <Ctrl> F10;
- a function key pressed with the <Alt> key: <Alt> F1 to <Alt> F10; and
- the keys <PgUp> and <PgDn>.

Graphics Output

RAMBO I can generate and plot graphically four different traffic-flow theory curves:

- Speed vs. Density;
- Flow vs. Speed;
- Flow vs. Density; and
- Flow vs. Occupancy.

The graphics output is generated in a part of the program called the Ramp Plan Evaluation screen. The traffic-flow curves and their meaning will be explained later in this chapter, after RAMBO I screens are presented and when the Ramp Plan Evaluation screens are introduced in detail.

Interactive Editing Screens

An interactive editing screen is a rectangular part of the screen which consists of displayed messages, editable fields, and command key selections. In RAMBO I every interactive editing screen is associated with a specific function which is clearly indicated by the title of the screen's window. More specifically, a user may find the following items on a screen:

Editable Fields;
Command Keys; and
Displayed Messages.

Editable fields are portions of the screen which display messages that may be fully edited by the user. Editable fields are shown in a distinct color from that of the screen's background. A screen usually consists of a number of fields which the user may "visit" one-by-one using the screen's navigation keys shown in Table 2-1.

TABLE 2-1. Navigation Keys in a RAMBO I Screen.

Key	Action
<ENTER>	Move to the next field in logical sequence.
<Down Cursor þ>	Move to the next field in logical sequence.
<Up Cursor þ>	Move to the previous field in logical sequence.
<Home>	Move to the first editable field of the form.
<End>	Move to the last editable field of the form.
<Tab>	Move to the field found on the right
<Shift-Tab>	Move to the field found on the left.

When the user presses a navigation key to select another screen field, the cursor moves to the rightmost position of this field, its color changes to a bright white foreground on light green background, and the system encloses it with square brackets "[.....]". The change of the color makes it easy for the user to immediately identify the currently selected field of the screen. The brackets around a selected field give an exact indication of the maximum size of this field. Updating or entering fresh data in a field is the primary way that users may enter keyboard input to RAMBO I. When a form is displayed, the first editable field is automatically selected.

RAMBO I excecutes specific actions or functions when specific command keys (function keys) in a screen are selected. The available command keys in the various RAMBO I screens are presented and each one of the forms is explained in detail.

RAMBO I displays information messages on the *displayed message* part of the screen. The user cannot change these parts of the screen.

Field Editing

RAMBO I allows full editing of all modifiable screen fields. When a screen field is selected, the field color changes to bright white foreground on light green background and square brackets appear along the field's sides. The cursor is automatically positioned under the leftmost field position. While editing a field, any editing operation shown in Table 2-2 may be used.

TABLE 2-2. Interactive Field Editing.

Key	Action
<Left-> or <Right-> cursor keys	Move the cursor left or right inside the current field, until one of the field's edge is reached.
<Ins> key	Toggle between insert ON and OFF.
<Del> key	Delete the character right above cursor and shrink the field's contents.
<Backspace> key	Delete the character immediately to the right of the current one and shift the field's contents one position left.
<Enter↵> key	Finalize the editing of the field and move to the next field in logical sequence.
Any Command Key	If this is a valid command key then RAMBO I executes the intended activity, else a beeping sound is generated.
<ESC> key	This key cancels the last modifications on the current field, only.

All editable fields in RAMBO I screens are *fully interactive*: as soon as a new value is entered in a field, RAMBO I automatically recalculates all other fields whose values depend on the contents of the field that was most recently updated. This happens as soon as the user

presses any screen navigation key and moves outside the editable field. More specifically, whenever the user leaves an editable field, RAMBO I checks if this field has been updated, and if so, it performs an initial value validation on the new field's contents. If the entered value is within acceptable ranges and of the correct type, RAMBO I recalculates the value of any other field whose contents depend on the most recently modified field. The field contents are redisplayed as soon as their new values are re-computed. This occurs instantaneously so the user may not notice it.

Whenever a user enters incorrect or meaningless values to a field, RAMBO I rejects the new data, displays a message window on the screen notifying the user that the new data was rejected and restores the previous field contents.

File Management

RAMBO I uses two sets of data to generate the transition tables of a metered ramp. These are the freeway section traffic parameters and the signal timing table data. These two pieces of data we call Ramp Data. A user can save on data files the ramp data of different ramps. These files are called Ramp Data Files and, by convention, they have the extension "*.RMP". A user may retrieve ramp data again to update it and generate new transition tables for a ramp. The ramp files for all the ramps of a freeway can be stored in the same sub-directory for easy access. A user may thus maintain different directories which refer to different freeways or parts of the same freeway if desired.

There are four RAMBO I screens through which a user may store or retrieve data from files. In the main menu screen, a user can perform file-management operations on ramp data files by accessing the File Management screen. In this screen a ramp file may be created that will contain all data (the freeway section parameters and the signal timing table information) RAMBO I has at that time. An old ramp file may be retrieved for modifications, and transition table recomputation. RAMBO I saves the computed transition table with the four metering plans along with the ramp data at the end of a ramp file. The ramp files are plain text files which the user may access, edit or print using any text editor for MS-DOS.

In the Freeway Section Parameters screen, a user may separately save the freeway section traffic parameters data currently being worked with on a freeway data file. Freeway files by

convention have the extension "*.FW" as in "SEFWY.FW". Freeway data saved in the past may be retrieved again for modification or re-processing. In the Freeway Section Parameters screen, the user may also retrieve a ramp file. The freeway section parameters' files are plain text files that the user may access, print, etc. using any text editor for MS-DOS. The file-management operations will be explained in more detail in the Freeway Section Parameters Screen part of the user's guide.

In the Signal Timing screen, a user may separately save the signal timing data currently working in a defined signal timing data file. Signal timing files by convention have the extension "*.MT" as in "SEFWY.MT". Signal timing data saved in the past may be retrieved again for modification or reprocessing. In the signal timing screen, the user may also retrieve a signal timing file that was saved in the past. The signal timing table files are plain text files that the user may access, print, etc. using any text editor for MS-DOS. The file-management operations of this screen will be explained in more detail in the Signal Timing Screen part of this chapter.

In the Transition Table screen, the user may separately save the generated transition point table having the four metering plans of the current ramp in a Transition Table file. Transition Table files by convention have the extension "*.TT" as in "MYRAMP.TT". The transition table files are plain text files that the user may access, print, etc. using any text editor for MS-DOS.

Help Screens

Every major screen of RAMBO I is accompanied by a *help* screen which is accessible by pressing the Command key F9. The information on each help screen is related to the screen the user is currently working on. Key variables are defined, ranges of applications noted, and some limited guidelines are provided.

RAMBO I SCREENS

RAMBO I consists of the following main screens:

- Main Menu;
- Freeway Section Parameters;
- Signal Timing Table;
- Transition Table; and
- Ramp Plan Evaluation.

The user can also access Related File Management, Help, and Utility screens. The screens of RAMBO I are described in the next sections.

Main Menu Screen (F1)

The Main Menu screen is the top-level menu of RAMBO I. All other screens are accessible from this screen. The Main Menu screen is shown in Figure 2.1.

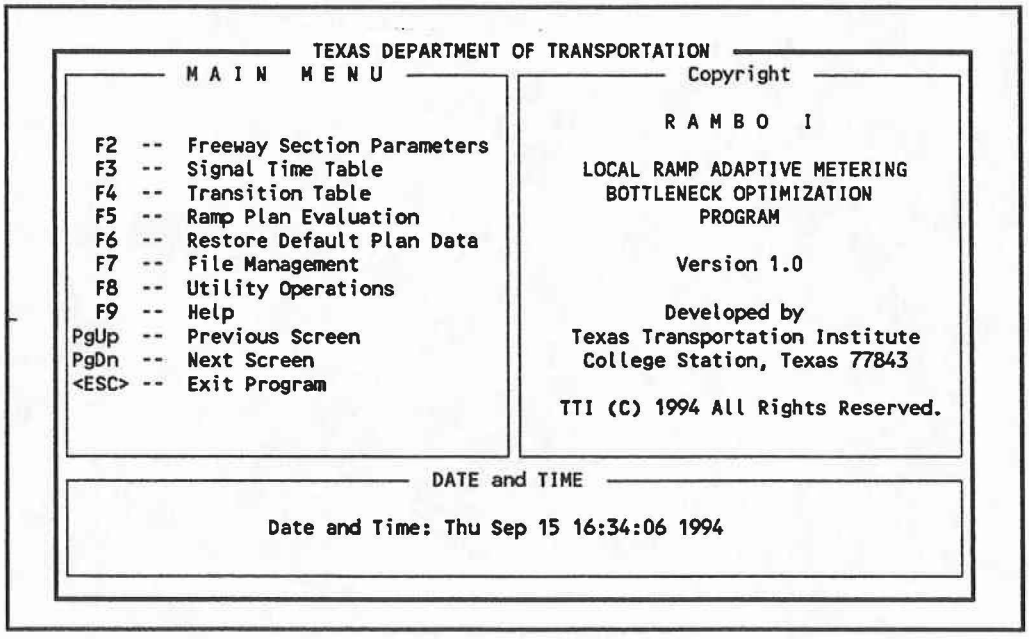

FIGURE 2.1. Main Menu Screen of RAMBO I.

Commands

The Main Menu contains the following options.

F2: Go to the Freeway Section Parameters screen to enter or retrieve freeway section traffic parameters data for up to 4 metering plans;

F3: Go to the Signal Timing screen to specify or retrieve Red-Yellow-Green times for a ramp;

F4: Go to the Transition Table screen to view or save the generated transition point tables for the 4 plans of the current ramp;

F5: Go to the Ramp Plan Evaluation screen to specify upstream flow or occupancy, to get metering levels, the downstream freeway state, and generate the four traffic-flow graphs;

F6: Restore default values for the freeway section parameters and metering tables data;

F7: Go to the File Management screen of the Main Menu to save, retrieve, edit or print Ramp data files;

F8: Go to the Utility Operations screen to view memory usage, use the MS-Editor, or exit temporarily to a DOS prompt;

F9: Go to the Main Menu Help screen;

<PgUp>: Go to the screen which logically precedes the RAMBO I screen accessed last;

<PgDn>: to the screen which logically follows the RAMBO I screen accessed last; and

<ESC>: Terminate RAMBO I Program.

File Management in the Main Menu

The file management screen which is shown in Figure 2.2 allows the user to specify a file in which to save the ramp data RAMBO I is currently using or to specify the file from which RAMBO I should retrieve ramp data.

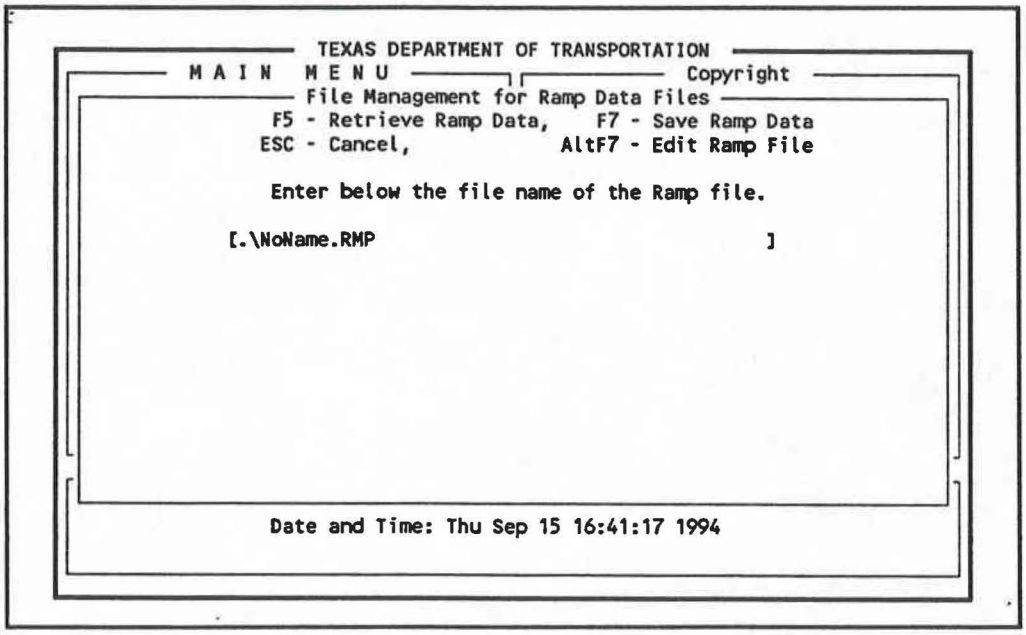

FIGURE 2.2. File Management Screen in Main Menu for Ramp Data Files.

In the File Management screen in the Main Menu, the user may perform the following operations:

F5: Specify an existing file from which to retrieve Ramp data. The file should have the extension "*.RMP";

F7: Save the current Ramp data of RAMBO I on a data File. By convention this file should end in "*.RMP";

AltF7: Use the MS-EDIT command to edit or Print a Ramp Data file. Note that the path of the Edit command must be in the Path DOS environment variable;

F9: Display the Help Screen for File Management; and

<ESC>: Cancel the File Operation and return to Main Menu screen.

If you specify an existing ramp file in a save operation, then RAMBO I will overwrite the existing file with the new data. If you attempt to open an non-existing file or if the filename is not formed properly, then RAMBO I displays a "File Open Error" information screen, like the one shown in Figure 2.3.

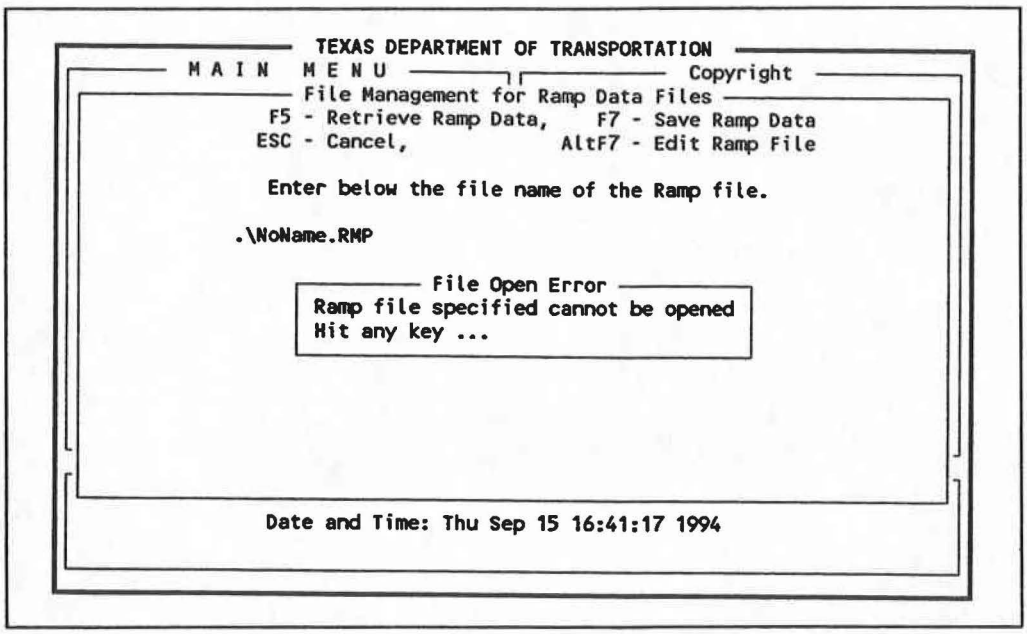

FIGURE 2.3. Open File Error Screen.

The Freeway Section Parameters Screen (F2)

In the Freeway-Section Parameters screen, the user enters all the traffic-flow data related to the current section of the freeway (See Figure 2.4). Data for up to four metering plans can be entered. Each plan occupies a separate *column* of the Freeway-Section Parameters screen. The plans are numbered from 1 to 4, with metering plan 1 having the highest service capacity.

Successive metering plans must have progressively lower service capacities. Service capacities are calculated when percentages of ideal capacity are entered. Invalid or out-of-range values entered are rejected by RAMBO I. Previous values are restored in the field.

Data Entry Fields

In the Freeway Section Parameters screen, the user may enter or update information on the fields labeled on the screen. Each field is described below.

FREEWAY SECTION PARAMETERS

F1-Main Menu, F5-Files, PgUp-Previous Screen, PgDn-Next Screen, F9-Help
Enter freeway parameters for each ramp metering plan.

Freeway Name [US 59 Southwest Freeway.]
Flow Direction (N,S,E,W) E
Metered Ramp Name Ramp 1 -- SE of GreensPoint Mall.
Ideal Capacity Per Lane 2400 vphpl

Metering Plan Number	1	2	3	4
Downstream Freeway Lanes	3	3	3	1
Fwy Capacity, ideal, vph	7200	7200	7200	2400
Fwy Capacity, service, vph	7200	6912	6624	2112
Percent Ideal Capacity, %	100.0	96.0	92.0	88.0
Capacity Speed, mph	45.0	45.0	45.0	45.0
Free Speed, mph	65.0	65.0	65.0	65.0
Capacity Density, vpm	160.0	160.0	160.0	53.3
Jam Density, vpm	450.0	450.0	450.0	150.0
Detector Length, feet	21	21	21	21
Detector Location, (U,D)	U	U	U	U
Flow Conditions, (S,U)	S	S	S	S
Metering Adjustment Factor	1.0	1.0	1.0	1.0
Coefficient 'l'	3.628	3.628	3.628	3.628
Coefficient 'm'	0.814	0.814	0.814	0.814

FIGURE 2.4. Freeway Section Parameters Screen.

Freeway Name. This is the name of the freeway where the ramp of interest is located. The freeway name may be up to 40 alphanumeric characters long. When no name is specified, RAMBO I supplies the default freeway name "NoName".

Flow Direction. Traffic flow direction may be N for North bound, S for South bound, E for East bound, and W for West bound. When no direction has been entered, the system supplies a "-" character to indicate this fact.

Metered Ramp Name. The user may give a name to the ramp of interest. The name may be up to 40 alphanumeric characters long. If no ramp name has been entered, the system supplies the default name "NoName".

Ideal Capacity Per Lane. The *Ideal Capacity Per Lane* is the maximum capacity flow of vehicles per hour per freeway lane. The system by default initializes this field to 2400

vphpl. The user may modify this value together with speed at capacity as needed to best fit observed freeway traffic flow during free flow conditions.

Downstream Freeway Lanes. The *Downstream Freeway Lanes* is the number of lanes on the freeway immediately downstream of the metered ramp of interest.

Fwy Capacity, ideal. This field is the ideal freeway capacity downstream per freeway section and it is calculated by the system as follows:

$$\textit{Fwy Capacity ideal} = \textit{Ideal Capacity per Lane} \times \textit{Downstream Freeway Lanes}$$

This field is used only for information display, so the user may not directly modify it. When either *Ideal Capacity per Lane* or *Downstream Freeway Lanes* change, the system automatically updates this field.

Fwy Capacity, service. This is the desired service freeway capacity immediately downstream of the ramp for each metering plan. It is computed automatically by the system as follows:

$$\textit{Fwy Capacity service} = \textit{Fwy Capacity ideal} \times \textit{Percent Ideal Capacity}$$

The system automatically recomputes and redisplays the Service Freeway Capacity every time the user changes the value of *Ideal Capacity per Lane*, *Downstream Freeway Lanes,* or *Percent Ideal Capacity* described below.

Percent Ideal Capacity. The *Percent Ideal Capacity* indicates the percentage of *Fwy Capacity, ideal* which is considered as the service capacity of the freeway link. The user selects a specific percentage for each one of the metering plans of the ramp. The system assigns to the *Fwy Capacity, service* for each of the four metering plans the following percentages of their corresponding *Fwy Capacity, ideal.*

Plan 1: *Fwy Capacity, service* = 100% of *Fwy Capacity, ideal;*
Plan 2: *Fwy Capacity, service* = 96.0% of *Fwy Capacity, ideal;*
Plan 3: *Fwy Capacity, service* = 92.0% of *Fwy Capacity, ideal;* and
Plan 4: *Fwy Capacity, service* = 88.0% of *Fwy Capacity, ideal;*

Capacity Speed. The *Capacity Speed* is the average speed of the traffic at ideal capacity of the freeway, in miles per hour. The system supplies the default value 45 miles per hour (72 kilometers per hour).

Free Speed. The *Free Speed* is the free-flow speed of the traffic on the freeway in miles per hour. The system supplies the default value of 65 miles per hour (105 kilometers per hour).

Capacity Density. The *Capacity Density* is the density of vehicles in the freeway flow in vehicles per mile. This is the average density when the vehicles travel on the freeway at the ideal capacity speed. The system computes *Capacity Density* as follows:

$$\textit{Capacity Density} = \textit{Fwy Capacity, ideal} \;/\; \textit{Capacity Speed}$$

When either *Fwy Capacity, ideal*, or *Capacity Speed* is updated by the user, the system automatically updates this field.

Jam Density. The Jam Density is the density of vehicles when the freeway is jammed in vehicles per mile per section. The system calculates the *Jam Density* as follows:

$$\textit{Jam Density} = 150 \times \textit{Downstream Freeway Lanes.}$$

When the user modifies the *Downstream Freeway Lanes*, the system automatically updates *Jam Density.*

Detector Length. The *Detector Length* is the length of the detection zone in feet. The system supplies a default value of 21 feet (6.4 meters), 6 feet(1.83 meters) +15 feet (4.6 meters), which the user may modify.

Detector Location. The *Detector Location* for freeway occupancy measurement may be "U" for upstream or "D" for downstream. The Detector Location by default is "U".

Flow Conditions. The *Flow Conditions* may be "S" for "Stable" or "U" for "Unstable". Stable means that the upstream flow has not exceeded the downstream service capacity. Unstable

means that the user believes the upstream flow has exceeded the freeway service capacity and it is about to break down downstream of the ramp, or perhaps is already congested.

Metering Adjustment Factor. The *Adjustment Factor* is not fully utilized in this version of RAMBO I. It deals with adjusting the ramp metering rates up or down by some fixed ratio.

Coefficients 'l' and 'm'. The *l* and *m* coefficients are computed given the traffic flow parameters the user enters in the Freeway Section Parameters screen. RAMBO I computes the traffic flow coefficients every time a new value is entered in the above specified editable fields. They determine the size and the shape of the traffic flow curves from which RAMBO I computes the occupancy levels in each of the metering plans. The coefficient can be viewed from the Ramp-Plan Evaluation screen.

Commands

The following Command Keys can be used in the Freeway Section Parameters Screen:

F1:	Return to Main Menu;
F9:	Go to the help screen for Freeway Section Parameters;
<PgUp>:	Return to previous screen (Ramp Plan Evaluation screen);
<PgDn>:	Proceed to next screen (Signal Timing screen);
<ENTER>:	Receive the current field updates and move to next editable field of a plan;
TAB:	Move right of current field; and
ShTAB:	Move left of current field.

File Management for Freeway Data Files

In the File Management screen, which is shown in Figure 2.5, the user can save the current freeway data onto a freeway file or can ask RAMBO I to retrieve freeway data from a freeway file already saved. Freeway files should end in "*.FW" for clear distinction from other types of files that RAMBO I or other foreign applications use.

In the File Management Window of Freeway Section Parameter, one can retrieve Freeway data from a freeway file (`*.FW') or save the data of the Freeway Section Parameters screen to a freeway file. One may retrieve Ramp data stored on a Ramp file (`*.RMP') or one can save the current Ramp's data on a Ramp file. Additionally, one can use the MS Editor to edit and modify or print any file. When one specifies an existing filename in a `Save Ramp (or Freeway) Data' operation, the old file is overwritten with the new data.

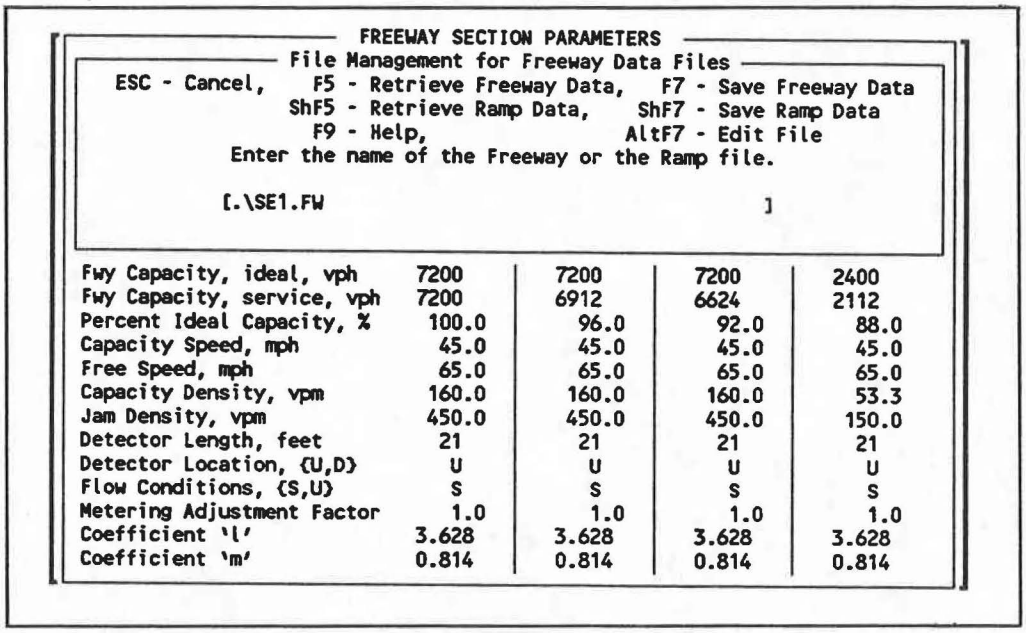

FIGURE 2.5. File Management Screen in the Freeway Section Parameters Screen.

The following functions are available:

F5: Specify and retrieve an existing Freeway file (`*.FW');

F7: Save current Ramp's data on a file (`*.FW');

ShF5: Specify and retrieve an existing Ramp file (`*.RMP');

ShF7: Save current Ramp's data on a file (`*.RMP');

AltF7: Use MS Editor to Create/Modify or PRINT a text file;

F9: Go to the Help Screen for Freeway Section Parameters File-Management; and

<ESC>: Cancel File Operation and return to Freeway Section Parameters Screen.

Signal Timing Table Screen (F3)

In the Signal Timing Table screen of RAMBO I, the user can modify the signal timing data which are to be used for the current ramp (see Figure 2.6). The vehicles per cycle may also be set. Any change automatically updates the target average flow rates and the threshold points of the metering rates shown in the two bottom rows of the screen. The average flow rates are *target* flows from the ramp. There is one average flow rate for each of the seven metering rates B, C, D, E, F, G, and H. The threshold values are flow rates that switch from one metering level to another metering level. When the user enters improper input values in a field, the system rejects them and restores the previous field values.

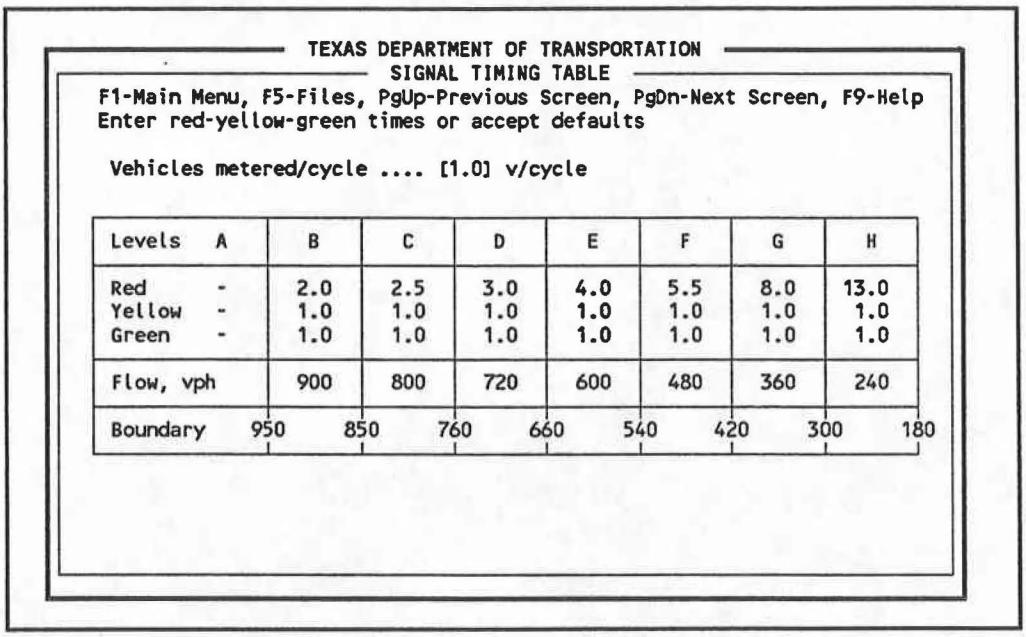

FIGURE 2.6. Signal Timing Table Screen.

Data Entry Fields

In the Signal Timing Table screen of RAMBO I, a user may enter or update information on the following fields:

Vehicles metered per cycle. In this field the user enters the average number of vehicles that enter the freeway from the metered ramp per cycle.

In the next three lines of the screen, the user may modify the red, yellow, and green times of the meter cycles associated with the seven metering levels: B, C, D, E, F, G, and H, respectively. Metering level A is a non-metered condition.

Red. There are seven red fields in the screen, each associated with one of the seven metered levels. The system default values for the seven levels of red times are:

2.0, 2.5, 3.0, 4.0, 5.5, 8.0, and 13.0 sec.

The user may modify them as desired. Every time a change is made to any of the red times, the system automatically updates the mid-point flow rates and the boundary flow rates of the associated metering levels.

Yellow. There are seven fields for the yellow times, one for each of the seven metering levels as described above. The system's default values are all set at 1.0 second of yellow time. The user may modify them as desired.

Green. There seven fields for the green times, one for each of the seven metering levels, all set by default to 1.0 second. The user can make changes as desired.

In the two bottom rows the screen shows the Average Flow Rates labeled *Flow* and the threshold flow values labeled *Boundary.*

The Target Average Flow Rates are the number of cars the ramp would allow to enter the freeway per hour. These are computed automatically by the system given the *Vehicles Metered per Cycle* field and the *Red, Yellow* and *Green* times provided. Given the default values specified above, the system shows: 900, 800, 720, 600, 480, 360, and 240 vehicles per hour, for metering levels B, C, D, F, G, and H, respectively.

The threshold points are the flow rates midway between the above mentioned target average ramp metering rates. They are computed automatically by RAMBO I. Given the above mentioned default values, RAMBO I shows on the screen: 950, 850, 760, 660, 540, 420, and, 300 vehicles per hour as the threshold values for the seven metering levels, respectively. When a user updates the times or the *Vehicles Metered per Cycle,* RAMBO I automatically recomputes the new mid-points and displays them on the screen.

Commands

At the Signal Timing Table screen, the user may execute the following command keys:

F1:	Return to Main Menu Screen;
<PgUp>:	Return to previous screen (Freeway Section Parameters Screen);
<PgDn>:	Proceed to next screen (Transition Table Screen);
F9:	Go to the Signal Timing Table Help screen;
<ENTER>:	Move to next form field;
TAB:	Move right of current field; and
ShTAB:	Move left of current field.

File Management for Signal Timing Table

In the File Management Window of Signal Time Table screen, the user can retrieve data from a Signal Time Table File ("*.MT") or save the data of the Signal Time Table screen in a file. Additionally, the user may invoke the MS-Editor to edit and modify or print a signal timing file. When an already existing file is named in a "Save Signal Time Data" operation, the old file is overwritten by the new data. The File Management Screen of the Signal Timing screen is shown in Figure 2.7.

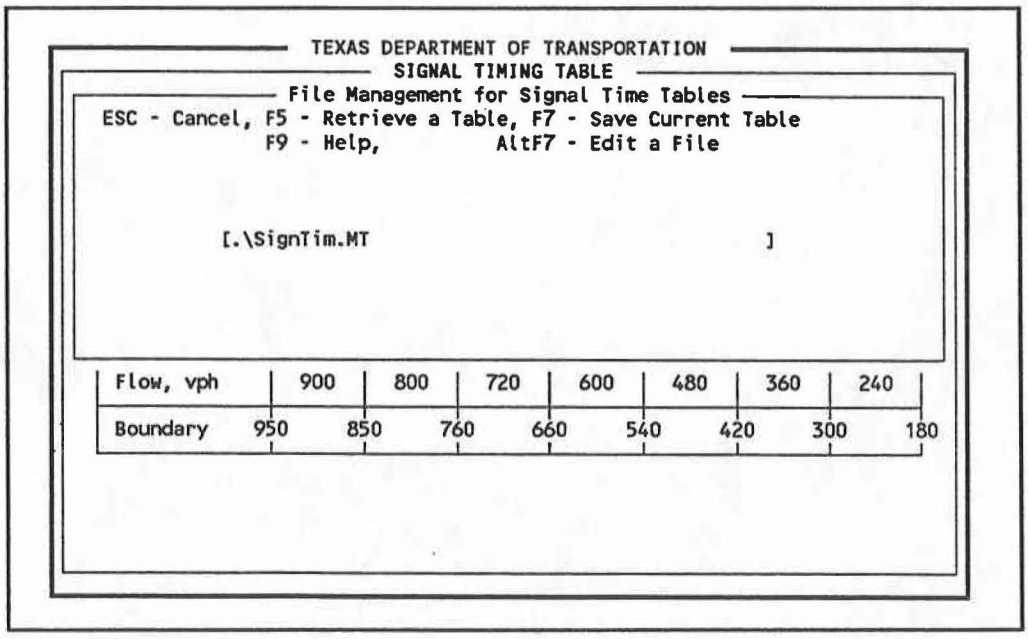

FIGURE 2.7. File Management Screen in the Signal Table Screen.

The following Command Keys are available.

F5: Specify and retrieve an existing Signal Time file. The file should end to "*.MT", by convention;

F7: Save current Signal Time Table data on a file with the file extension as *.MT";

AltF7: Use MS-Editor to Create, Modify, or PRINT a text file;

F9: Go to the Signal Timing Table File Management Help screen; and

<ESC>: Cancel File Operation.

Transition Table Screen (F4)

In the Transition Table screen, the user may view the occupancy transition points in terms of measured upstream freeway occupancy in percent of the time the detection length would be occupied. A sample Transition Table screen is shown in Figure 2.8.

The eight rows correspond to the different metering levels from A to H. The leftmost column shows the metering level. The next two columns show the red, yellow and the green times selected for this level. The next column shows the mid-point metering rate corresponding to this level. The four rightmost columns show the percent lane occupancy at the transition points when exceeded switch operations to the next lower metering rate. The occupancy columns indicate that when the measured occupancy is between the one shown on a row and the one on the row above it, then we meter at the level associated with this row. Note that meter level H is used for all occupancies higher than meter level G.

RAMBO I generates the transition table as soon as the user selects valid input data for freeway-section parameters and signal timing table data. This screen is read-only.

TRANSITION TABLE

F1 - Main Menu, PgUp - Previous Screen, PgDn - Next Screen, F9 - Help,
F5 - Save Transition Table on a File, F7 - Edit or PRINT a File.

Metering Level	Red, Yellow, and Green Times	Meter Rate	Plan 1 Occ. %	Plan 2 Occ. %	Plan 3 Occ. %	Plan 4 Occ. %
A	* * *	*	14.5	13.6	12.7	7.2
B	2.0, 1.0, 1.0	900	15.0	13.9	13.0	8.0
C	2.5, 1.0, 1.0	800	15.2	14.3	13.2	8.5
D	3.0, 1.0, 1.0	720	15.8	14.5	13.6	9.3
E	4.0, 1.0, 1.0	600	16.4	15.1	13.9	10.1
F	5.5, 1.0, 1.0	480	17.0	15.6	14.4	11.0
G	8.0, 1.0, 1.0	360	17.6	15.9	15.0	12.0
H	13.0, 1.0, 1.0	240	18.2	16.5	15.3	13.0

* Indicates Non-Metered condition.

FIGURE 2.8. Transition Table Screen of RAMBO I.

Commands

F1: Return to Main Menu screen;

<PgUp>: Return to previous screen (Signal Timing Table screen);

<PgDn>: Proceed to next screen (Ramp Plan Evaluation screen);

F5: Save a Transition Table on a File or Edit the file of a Transition Table; and

F9: Go to the Signal Timing Table Help screen.

The user may save the generated transition table onto a transition table file which must end in "*.TT" for future reference. The transition table saved on the file need not be retrieved by RAMBO I, since its contents are recomputed every time the user specifies freeway section parameter and signal timing table data for a ramp.

Ramp Plan Evaluation Screen (F5)

In the Ramp Plan Evaluation Screen of RAMBO I, the user may evaluate the performance of the metered ramp at the specified level of the input parameters of the system. A sample Ramp Plan Evaluation screen is shown in Figure 2.9.

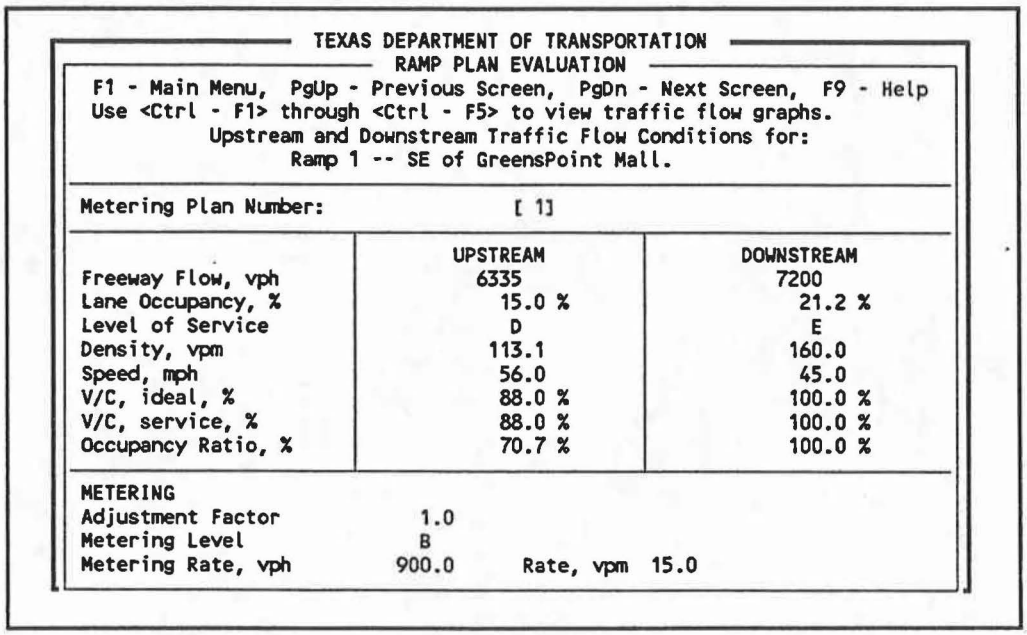

FIGURE 2.9. Ramp Plan Evaluation Screen.

The user selects a plan number (1-4) and enters the flow or occupancy upstream of the ramp. The corresponding upstream traffic flow conditions and resulting metering rates are displayed, assuming *downstream freeway flow is at the service capacity of the metering plan.* Traffic flow graphs of upstream traffic conditions are generated for the given upstream conditions, using command keys <CtrlF1> through <CtrlF5>. The right column of the screen shows the traffic flow conditions downstream of the ramp, assuming that the flow is at the service capacity selected.

Data-Entry Fields

Metering Plan Number. The user selects one of the four metering plans (1-4).

Freeway Flow (UPSTREAM). When the user enters the *Freeway Flow* upstream of the ramp, the system automatically computes the corresponding upstream percent occupancy. The system also automatically computes the upstream level-of-service, density, speed, percent of upstream flow of ideal downstream capacity (*V/C, ideal*), percent of upstream flow to service downstream capacity (*V/C, service)*, occupancy ratio, metering level, and the metering rates in vehicles per hour and vehicles per minute.

Lane Occupancy (UPSTREAM). When the upstream *Lane Occupancy* is entered, the system automatically computes the upstream freeway flow, level-of-service, density, speed, percent of upstream flow of ideal downstream capacity (*V/C, ideal*), percent of upstream flow of service downstream capacity (*V/C, service)*, occupancy ratio, metering level, and the metering rates in vehicles per hour and vehicles per minute.

Level of Service (UPSTREAM). This value is computed automatically by the system when *Freeway Flow* or *Lane Occupancy* is entered.

Density. The upstream freeway density is computed automatically by the system when *Freeway Flow* or *Lane Occupancy* is entered.

Speed. The upstream freeway speed is computed automatically by the system when *Freeway Flow* or *Lane Occupancy* is entered.

V/C, ideal. The V/C ratio *ideal* is computed automatically by the system when *Freeway Flow* or *Lane Occupancy* is entered.

V/C, service. The upstream *V/C, service* ratio is computed automatically by the system when *Freeway Flow* or *Lane Occupancy* is entered.

Occupancy Ratio. The upstream *Occupancy Ratio* (occupancy divided by occupancy at ideal capacity) is computed automatically by the system when *Freeway Flow* or *Lane Occupancy* is entered.

Adjustment Factor. This field is not fully utilized by the current version of RAMBO I. It is reserved for future enhancements.

Metering Level. This is the metering level that the metered ramp should meter at given the entered value of upstream *Freeway Flow* or *Lane Occupancy*.

Metering Rate. This is the average ramp metering rate in vehicles per hour corresponding to the metering rate shown in *Metering Level.*

Rate, vpm. This is the average ramp metering rate in vehicles per minute corresponding to the metering rate shown in *Metering Level.*

Commands

Functions available on the Ramp Plan Evaluation screen include:

F1:	Return to Main Menu screen;
F9:	Go to the Ramp-Plan Evaluation Help screen;
<PgUp>:	Return to previous screen (Transition Table screen);
<PgDn>:	Proceed to next screen (Freeway Section Parameters screen);
Ctrl-F1:	Generate *Speed vs. Density* graph;
Ctrl-F2:	Generate *Flow vs. Speed* graph;
Ctrl-F3:	Generate *Flow vs. Density* graph;
Ctrl-F4:	Generate Flow vs. Occupancy;.
Ctrl-F5:	Generate and show all of the above graphs;
<ENTER>	Move to next form field;
<CUR↑>:	Move one field up;
<CUR↓>:	Move one field down;
<TAB>:	Move one field right; and
<ShTAB>:	Move one field left.

Traffic Flow Curve Graphical Output

In the Ramp Plan Evaluation screen, RAMBO I generates four traffic-flow graphs as shown in Figure 2.10. The following graphs are accessible by pressing the following command keys:

Ctrl-F1: *Speed vs. Density*;
Ctrl-F2: *Flow vs. Speed*;
Ctrl-F3: *Flow vs. Density*;
Ctrl-F4: *Flow vs. Occupancy*; and
Ctrl-F5: All of the above graphs.

The upstream traffic conditions are depicted on the traffic flow graphs. However, the downstream service capacity selected for the metering level is not, as yet, shown.

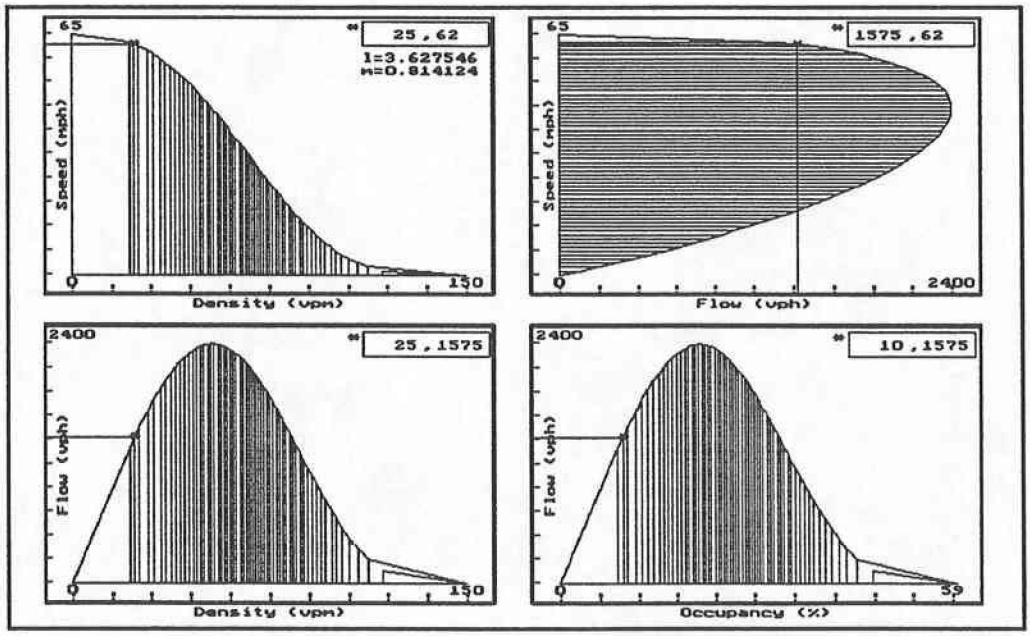

FIGURE 2.10. The Four Traffic Flow Graphs Screen.

3. RAMBO II

This chapter is the user's guide for the RAMBO II system. It provides a brief description of the three modules that comprise the RAMBO II system and a detailed description of the user interface module. It introduces the five screens that make up the user interface module with a detailed description of the data elements and options that are available in every screen.

OBJECTIVE

The RAMBO II system ramp metering program enables the user to optimize the traffic flow in a freeway system. A freeway system is a directional segment of the freeway that may contain up to 12 metered entrance ramps and 12 exit ramps along one direction of freeway traffic flow. The total distance of the segment is not restricted. RAMBO II consists of three separate and functionally distinct modules:

- User Interface;
- Optimization; and
- Local Ramp Metering (RAMBO I).

The three modules are independent of each other. They share information through external files and are linked together by batch files. The user interacts with the system through the User Interface module. The RAMBO II input data needs and startup process are described below, followed by a detailed description of the User Interface.

DATA NEEDS

The basic input data needed in RAMBO II can be broken down into three categories:

- Geometric Data: Freeway link type (head of link is either an entrance or exit ramp), link distance, and number of freeway lanes;
- Traffic Data: Demand flow (freeway, ramps) for 5 or 15 minute intervals;

- Other Data: Capacity analysis data, merge quality, maximum queue, and ramp queue diversion potential.

STARTUP PROCESS

The following steps begin the RAMBO II system:

1. Change directory to the subdirectory where the RAMBO II system is installed;
2. Type "rambo" at the prompt (The User Interface Module will be started and an opening screen containing a brief description of the system will be displayed); and
3. Hit any key to proceed. The Freeway System Specifications screen will be displayed with empty fields. The next section describing the User Interface module describes how to proceed.

USER INTERFACE

The User Interface module is the head of the RAMBO II system. It consists of five screens:

- Freeway System Specifications;
- Freeway System Parameters;
- Calibration Factors;
- Freeway System Operations; and
- File Management.

The Freeway System Specifications screen enables the user to enter the system specifications part of a freeway system input data file. The Freeway System Parameters screen allows the user to enter the freeway parameters part of an input file. The Freeway Traffic Operations screen provides the user with the capability of entering entrance and exit ramps flow besides displaying optimization results. The Calibrations Factors screen enables the user to change the values of the calibration factors, including *Ideal Capacity* per lane, *Service Capacity Meterplan Percentages*, *Free Speed*, *Jam Density* per mile per lane, *Detector Length*, *Cushion Factor*, *Freeway Measurement*, and the *Lane Use Alpha Factor*. The File Management screen allows the user to open a new file, load the previous file, load an existing

file, or save an input file. The following sections describe the data elements that each of the five screens displays and the options that the user can select in each screen.

The User Interface module has been designed to allow the user to move freely between the five screens. The only exception is the File Management screen which can only be accessed from the Freeway System Specifications screen. Although PgDwn and PgUp are not displayed as options in any screen, they can be used in the Freeway Traffic Operations screen to view the next or previous time slice information (every time slice is displayed in a separate screen).

Freeway System Specifications Screen (F1)

The Freeway System Specifications screen enables the user to enter the system specifications part of an input data file for a freeway system. The system specifications screen consist of the data elements as seen in Figure 3.1.

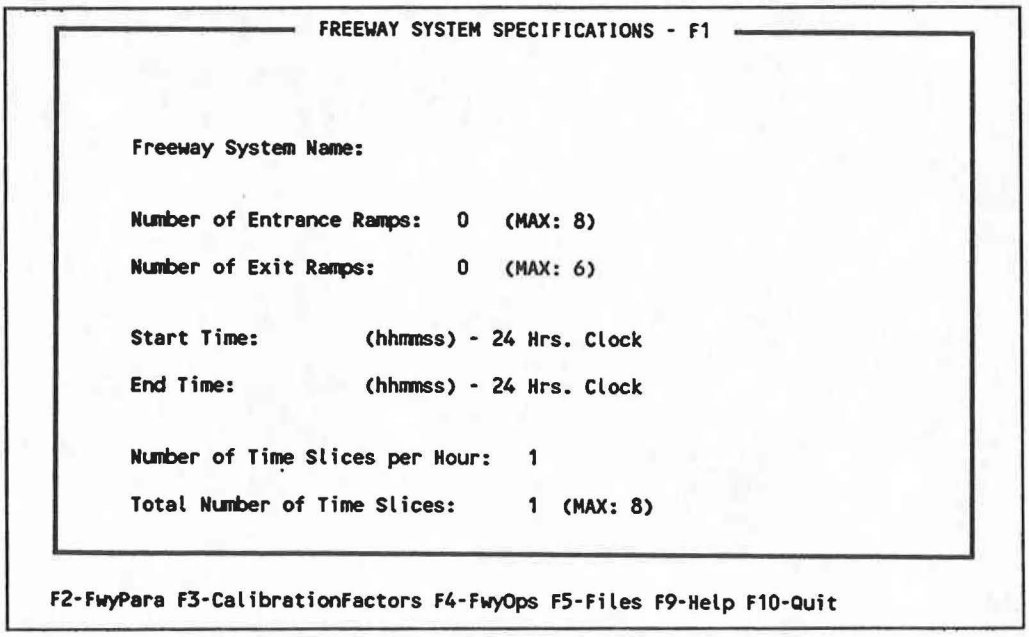

FIGURE 3.1. Freeway System Specifications Screen.

Data Entry Fields

Freeway System Name. The *Freeway System Name* identifies the freeway segment being analyzed. This field is 40 characters long and any alphanumeric character can be used as part of the name.

Number of Entrance Ramps. This field specifies the number of entrance ramps in the freeway system. This is a numeric field with a maximum value of 12 entrance ramps. This field cannot be modified and is automatically calculated by the system each time the user adds or deletes an entrance ramp in the Freeway System Parameters screen.

Number of Exit Ramps. This field specifies the number of exit ramps in the freeway system. This is a numeric field with a maximum value of 12 exit ramps. This field cannot be modified and is automatically calculated by the system every time the user adds or deletes an exit ramp in the Freeway System Parameters screen.

Start Time. The *Start Time* specifies the beginning time of the study. This field is not currently used in calculations.

End Time. The *Ending Time* specifies the ending time of the period of study. This field is not currently used in calculations.

Number of Time Slices per Hour. This field specifies the total maximum number of time slices per hour. It is a numeric field that depends on the length of the time slice. If, for example, the time slice length is 5 minutes, the number of time slices per hour is 60 divided by 5, which is 12.

Total Number of Time Slices. This field specifies the total number of time slices in the input file. Currently, the system can handle up to a maximum of 8 time slices. If the user enters a value greater than 8, the system will display an error message and wait for the user to change the value entered to a valid value not greater than 8.

Commands

The user can move to other screens by selecting one of the options displayed at the bottom of the Freeway System Specifications screen. The following options are available:

F2: Moves the user to the Freeway System Parameters screen;
F3: Moves the user to the Calibration Factors screen;
F4: Moves the user to the Freeway Traffic Operations screen;
F5: Moves the user to the File Management screen;
F9: Displays a help screen that provides definitions for both the data elements and options that can be selected from the screen; and
F10: Allows the user to exit the system.

Freeway System Parameters Screen (F2)

The Freeway System Parameters screen allows the user to enter or modify the freeway parameters of a freeway system. The user can enter information for a maximum of 12 entrance ramps and 12 exit ramps. The data elements that are displayed in this screen are seen in Figure 3.2.

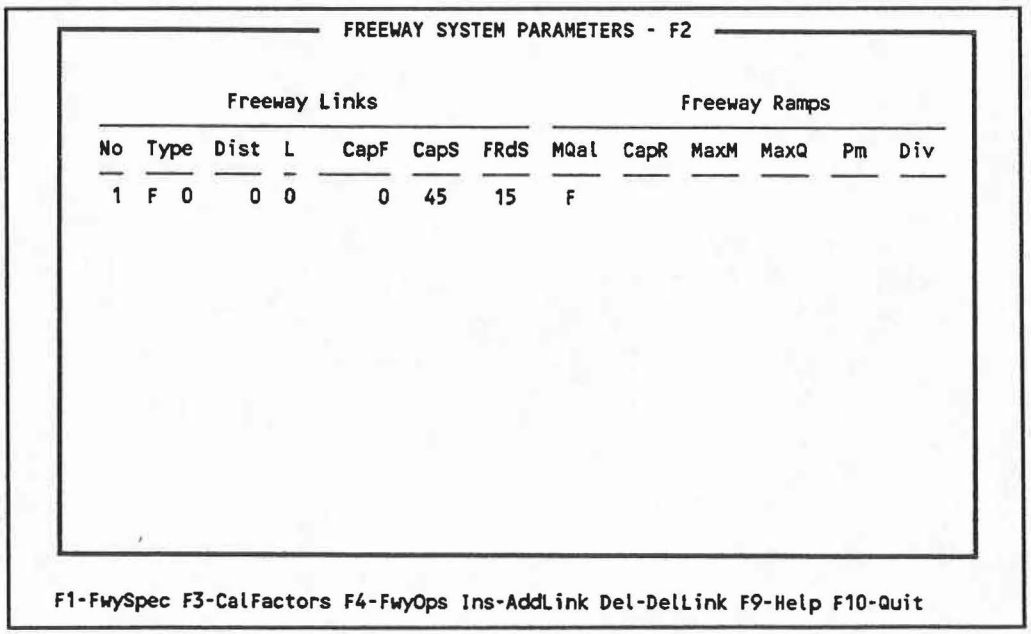

FIGURE 3.2. Freeway System Parameters Screen.

Data Entry Fields

Link Type (Type). The *Link Type* indicates whether the ramp at the head of the link is an entrance or exit ramp. The exception is the first row in this screen, which is always a type "F" link. The user cannot change the link type of the first row, because it represents the freeway input flow at the beginning of the freeway system being controlled. For the rest of the rows in the Freeway System Parameters screen, an "N" coded in the *Link Type* field indicates an entrance ramp at the head of the link. An "X" indicates an exit ramp at the head of the link. Any other character is rejected and the system will display an error message. Once the type of the link is entered (i.e., entrance or an exit ramp), the system will display the rest of the fields that apply. Links with entrance ramps at the head of the link have extra fields for traffic data that are not required for exit ramps. Default values can be subsequently overridden.

Link Distance (Dist). The *Link Distance* specifies the length of the freeway link. It is measured and input in feet.

Link Number of Lanes (L). The *Link Number of Lanes* specifies the number of freeway lanes in the direction of flow for the corresponding freeway link.

Link Capacity (CapF). The *Link Capacity* specifies the freeway link's service capacity in vph. The service capacity is the maximum flow rate permitted on the freeway link based on the traffic mix and geometric properties of the link. Coding 1, 2, 3, or 4 will be converted by the system into the corresponding meterplan service capacity, as specified in the Calibration Factors screen. A coded value higher than 4 will be accepted as a desired user specified freeway link service capacity. The minimum acceptable freeway link capacity is 1000 times the number of lanes for that link. The user should update the freeway link capacity every time changes are made in the number of lanes of a link. In order to remind the user, the link capacity is automatically set to the minimum, i.e., 1000 times the new number of lanes in that link, anytime the number of lanes of a link is changed. Also, when the 4 meterplan capacity percentages in the Calibration Factors screen are changed, the user must reenter the link capacities in the Freeway System Parameters screen. To avoid this data reentry, refer to the desired Order of Input Data Entry Procedure paragraph at the end of this document.

Link Capacity Speed (CapS). The *Link Capacity Speed* specifies the speed of the freeway flow for the link at ideal freeway capacity in miles per hour (mph). The default value is 45 mph (72 kilometers per hour). This primarily affects the traffic flow graphs.

Link Frontage Road Overall Travel Speed (FrdS). This field specifies the frontage road overall travel speed over the freeway link in mph. These are used to estimate the ramp origin-destination traffic patterns. Default values are provided: 35 mph (56 kmph) for entrance ramp and 15 mph (24 kmph) for exit ramp links, which assume a signalized diamond interchange is downstream of the exit ramp along the frontage road. A discontinuous frontage road link should have a speed value of about 5 mph (8 kmph). Freeways not having frontage roads should have speed values coded that reflect local freeway corridor conditions.

Ramp Merge Quality (MQal). Entrance ramps merge quality can be one of three values: "A", "B", or "C". "A" corresponds to a ramp merge point capacity on the freeway of 2200 vph, "B" = 2000 vph, and C = 1800 vph. The value of the merge quality field for exit ramps is set to "X" and cannot be changed by the user.

Ramp Merge Point Capacity (CapR). This field specifies the ramp merge point capacity, in the outside freeway lane, during metering. The system updates this field when the user enters the Ramp Merge Quality. However, the updated value can be modified by the user, if desired. The ramp merge point capacity is measured in vph.

Ramp Maximum Metering Rate (MaxM). This field specifies the maximum entrance ramp metering rate in vph. Generally, it is equal to 3600 divided by number of cycles per minute (cpm), where one vehicle enters per cycle. Appropriate adjustments would be made for other metering strategies and operational behavior.

Maximum Queue (MaxQ). The *Maximum Queue* specifies the maximum entrance ramp queue storage length. The ramp queue is measured in terms of number of vehicles that can be stored behind the meter. The default value is 50 vehicles.

Ramp Pm Factor (Pm). The *Ramp Pm Factor*, as calculated by the system, is the fraction of freeway arrival traffic approaching the meter in the merge lane. A preliminary value is calculated anytime the user enters/modifies the number of lanes in a link. However, *Pm* is recalculated by the system after the user enters the freeway demand information in the

Freeway Traffic Operations screen. This later value is used in the Optimization Module. The user may change the Pm system calculated value, if desired. However, once this is done, the system will always use the value that the user entered in the Optimization Module calculations. In order to reset the *Pm* value to be calculated by the system, the user must change the number of lanes in the link in the Freeway System Parameters screen. Anytime the number of lanes in a link is modified, the *Pm* value will be switched into the system-calculated mode again and will ignore any *Pm* value that was previously entered by the user for that link. *Pm* inversely varies with the *Lane Use Alpha Factor* field in the Calibration Factors screen.

Ramp Diversion Factor (Div). This field specifies the diversion factor for entrance ramp queue. It represents the fraction of potential entrance ramp queue that diverts to other ramps or leaves the freeway entirely.

Commands

The user can also move to other screens by selecting one of the options displayed at the bottom of the Freeway System Parameters screen. The following options are available:

F1: Moves the user to the Freeway System Specifications screen;
F3: Moves the user to the Calibration Factors screen;
F4: Moves the user to the Freeway Traffic Operations screen;
F9: Displays a help screen that provides definitions for both the data elements and options that can be selected from the screen; and
F10: Allows the user to exit the system.

Calibration Factors Screen (F3)

The Calibration Factors screen consists of a set of data elements whose values can affect the behavior of the system as a whole. The values of the fields in this screen should be checked and set to the desired values before proceeding with the process of either creating a new input data file or modifying an existing file. The Calibration Factors screen consists of the data elements as seen in Figure 3.3.

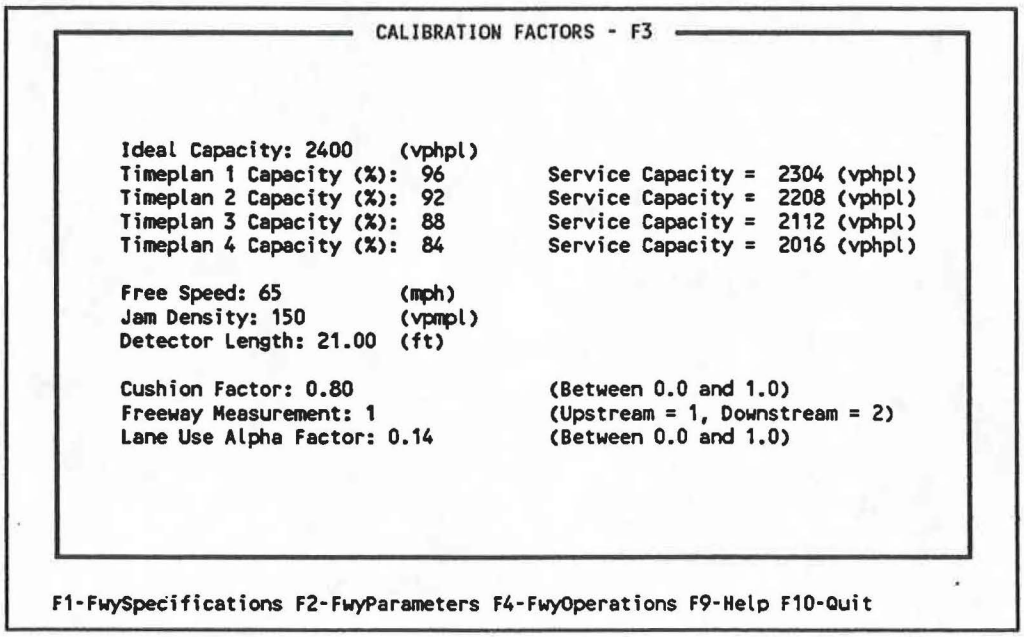

FIGURE 3.3. Calibration Factors Screen.

Data Entry Fields

Ideal Capacity. This field specifies the ideal freeway capacity of links in vehicles per hour per lane. It is to define the traffic flow graphs, and it can also be used to calculate service capacities for meterplans.

Timeplan 1 Capacity Percentage. This field specifies meterplan 1 service capacity per lane as a percentage of the *Ideal Capacity* per hour per lane. The system uses the percentage entered by the user to calculate Meterplan 1 service capacity, vphpl. Meterplan 1 service capacity, vphpl, is equal to *Meterplan 1 Capacity Percentage* x *Ideal Capacity,* vphpl. The resulting service capacity is displayed on the field adjacent to *Meterplan 1 Capacity Percentage* on the same line.

Timeplan 2 Capacity Percentage. This field specifies meterplan 2 service capacity per lane as a percentage of the *Ideal Capacity* per hour per lane. The system uses the percentage entered by the user to calculate Meterplan 2 service capacity, vphpl. Meterplan 2 service capacity, vphpl, is equal to *Meterplan 2 Capacity Percentage* x *Ideal Capacity*, vphpl. The

resulting service capacity is displayed on the field adjacent to *Meterplan 2 Capacity Percentage* on the same line.

Timeplan 3 Capacity Percentage. This field specifies meterplan 3 service capacity per lane as a percentage of the *Ideal Capacity* per hour per lane. The system uses the percentage entered by the user to calculate Meterplan 3 service capacity, vphpl. Meterplan 3 service capacity, vphpl, is equal to *Meterplan 3 Capacity Percentage* x *Ideal Capacity,* vphpl. The resulting service capacity is displayed on the field adjacent to *Meterplan 3 Capacity Percentage* on the same line.

Timeplan 4 Capacity Percentage. This field specifies meterplan 4 service capacity per lane as a percentage of the *Ideal Capacity* per hour per lane. The system uses the percentage entered by the user to calculate Meterplan 4 service capacity, vphpl. Meterplan 4 service capacity, vphpl, is equal to *Meterplan 4 Capacity Percentage* x *Ideal Capacity,* vphpl. The resulting service capacity is displayed on the field adjacent to *Meterplan 4 Capacity Percentage* on the same line.

The four meterplan capacity percentages correspond to the service capacity percentages used in RAMBO I to calculate transition tables for TxDOT's ramp meters. In RAMBO II, the meterplans' 1, 2, 3, and 4 service capacities, vphpl, can be used to calculate the total link capacity in the Freeway System Parameters screen when the user codes 1, 2, 3, or 4 in the *Link Capacity* field as described earlier. Here a link capacity will equal to the number of lanes in that link multiplied by the *Ideal Capacity,* vphpl, multiplied by the meterplan capacity percentage chosen by the user.

In RAMBO I, the user can specify 4 different meterplan capacity percentages for every ramp. However, in the current system version of RAMBO II, only a single set of 4 meterplan capacity percentages can be specified for all metered ramps in the freeway system. To easily incorporate system results into local meters, the same meterplan capacity percentages used in RAMBO II can also be used in RAMBO I.

Free Speed. This field specifies the free speed of the freeway flow in mph. The current default value for the freeway free speed is 65 mph (105 kilometers per hour).

Jam Density. This field specifies the jam density in terms of vehicles per mile per lane. The current default value used is 150 vpmpl (94 vpkmpl).

Detector Length. The *Detector Length* specifies the detection zone which is set to 21 feet (6.4 meters), assuming a standard 6 feet x 6 feet (1.83 meters x 1.83 meters) loop detector and assuming a 15-foot (4.6 meters) vehicle.

Cushion Factor. The *Cushion Factor* is a value between 0.0 and 1.0 that is used by the Optimization Module in determining the minimum metering rates to use. Minimum metering rates (MMR), used to establish equity among metered ramps, are automatically calculated based on the ramp demand data and the cushion factor. These MMR are then multiplied by the Cushion Factor to achieve one of the following results:

- If FCUSH is 1.0, the calculated MMR are used;
- If FCUSH is 0, MMR's becomes zero and no minimum rates are used; and
- If FCUSH is greater than 0.0 and less than 1.0, the MMR used will be the specified fraction of the initial MMR calculated values.

Metering rate equity is an especially important issue for a pair of adjacent on-ramps for which either there is no exit ramp between them, or the exit flow is negligible.

Freeway Measurement. The Freeway Measurement field indicates whether the volume measurements are upstream or downstream of the ramp being controlled. A value of 1 indicates that volume and traffic measurements are upstream, while 2 indicates that the measurements are downstream. Ramps are likely to be based on upstream measurement. Future ramp operation may be based on downstream measurement.

Lane Use Alpha Factor. This field specifies the merging lane use calibration factor, which is used by the system in calculating the Pm value. The alpha factor has a default value of 0.14 which is modifiable by the user. The alpha value should not be greater than 1/L where L is the number of lanes of the metered link.

Commands

The user can also move to other screens by selecting one of the options displayed at the bottom of the Calibration Factors screen. The options available are:

F1: Moves the user to the Freeway System Specifications screen;
F2: Moves the user to the Freeway System Parameters screen;
F4: Moves the user to the Freeway Traffic Operations screen;
F9: Displays a help screen that provides definitions for both the data elements and options that can be selected from the screen; and
F10: Allows the user to exit the system.

Freeway Traffic Operations Screen (F4)

This screen enables the user to specify the demand and exit flow for entrance and exit ramps. The user can use this screen to start the Optimization Module or RAMBO I for further analysis. The Freeway Traffic Operations screen consists of the data elements as seen in Figure 3.4.

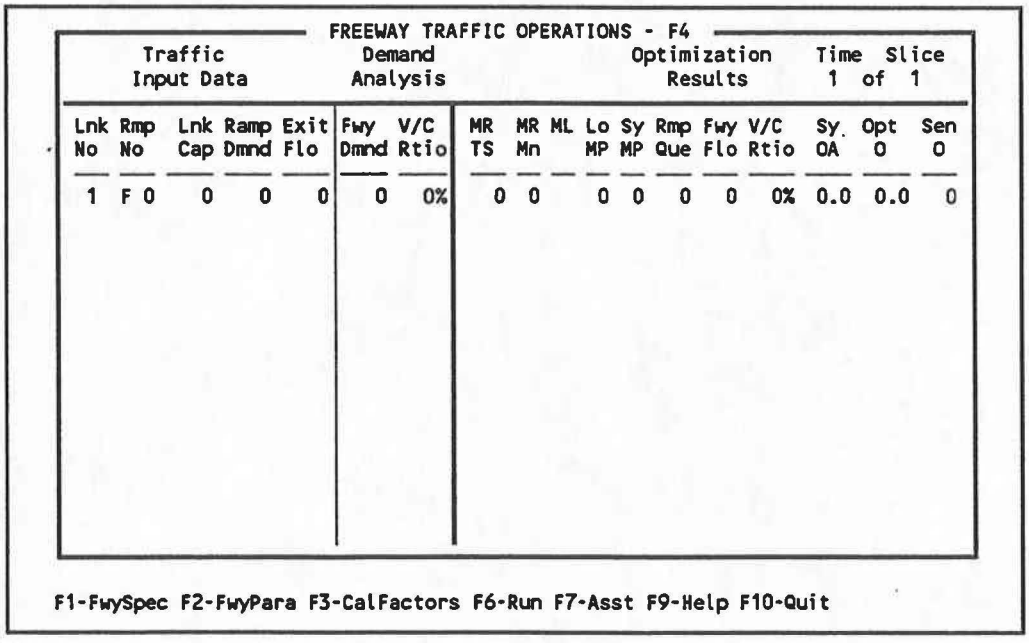

FIGURE 3.4. Freeway Traffic Operations Screen.

Data Entry Fields

Link Number (Lnk No.). The *Link Number* provides an ascending order count of the number of links in the freeway system, starting with the freeway link as 1.

Ramp Number (Rmp No.). The *Ramp Number* field consists of two parts. The first part indicates the type of the ramp at the head of the link and can be an "F" meaning that it is the freeway input, an "N" indicating an entrance ramp, or an "X" for an exit ramp. The first row in the freeway system is the only type "F" link. It represents the freeway conditions at the beginning of the freeway system being controlled. The second part of the Ramp Number field is a number indicating in ascending order the rank of the ramp within the ramp type specified in the first part of the field. For example, an "N 3" in the field means this ramp is the third entrance ramp downstream in the freeway system.

Link Capacity (Lnk Cap). The system calculates the *Link Capacity* per time slice. The *Link Capacity* per time slice is calculated by dividing the *Link Capacity per hour (CapF)*, which the user entered in the Freeway System Parameters screen, with the *Number of Time Slices per Hour* which the user entered in the Freeway System Specifications screen.

Ramp Demand (Rmp Dmnd). The *Ramp Demand* specifies the traffic demand flow (count) of entrance ramps in terms of vehicles per time slice, vpts. This field applies only for links that have an entrance ramp at the head of the link.

Exit Flow (Exit Flo). The *Exit Flow* specifies the traffic demand flow (count) of exit ramps in terms of vehicles per time slice, vpts. This field applies only to links with an exit ramp at the head of the link.

Freeway Demand (Fwy Dmnd). The *Freeway Demand* specifies the total demand on a freeway link in terms of vehicles per time slice vpts. The system calculates this value by adding to the initial freeway input, demand volume for the freeway system the *Ramp Demand* for entrance ramps and *Exit Flow* for exit ramps.

V/C Ratio. This is a ratio calculated by dividing the *Freeway Demand* field by the *Link Capacity*. It can be used to assess projected congestion and levels of service.

Metering Rate per Time Slice (MR TS). This field specifies the metering rate of an entrance ramp in vehicles per time slice, vpts. This field is calculated by the Optimization Module and cannot be modified by the user.

Metering Rate per Minute (MR Mn). This field specifies the metering rate of an entrance ramp in vehicles per minute. It is calculated by dividing the *Metering Rate per Time Slice* by the number of minutes in the time slice.

Metering Level (ML). The *Metering Level* is calculated by the system using TxDOT's ramp meter transition table. The ramp meter transition table has four meterplans that can be used at different times of the day. Each meterplan has information that maps metering rates to metering levels, or occupancy values to metering levels. The *Metering Rate*, as calculated by the Optimization Module, is used to find the corresponding *Metering Level* in the meterplan that is being used by the ramp meter during that time of day.

Local Metering Plan (Lo MP). This field specifies the TxDOT ramp metering plan that would have been selected based on local traffic conditions. Congestion may have resulted.

System Metering Plan (Sy MP). This field specifies the optimal TxDOT metering plan selected by RAMBO II based on the overall freeway system conditions. Freeway congestion should not arise unless the freeway input flow is excessive.

Ramp Queue (Rmp Que). The *Ramp Queue* specifies the metered ramp's queue at the end of the current time slice in terms of vehicles storing behind the signal. This field is calculated by the Optimization Module and cannot be modified by the user.

Freeway Flow (Fwy Flow). The *Freeway Flow* specifies the total metered volume on a freeway link in terms of vehicles per time slice. This field is calculated by the User Interface Module by adding to the freeway input flow at the beginning of the freeway system the metered flow of all entrance ramps and subtracting the total projected flow of all exit ramps preceding the current link.

V/C Ratio. The *V/C Ratio* is the freeway volume-to-capacity ratio calculated by dividing the metered *Freeway Flow* by the capacity of the link. Downstream bottleneck effects may limit the freeway flow allowed on the subject link. Also, upstream metered ramps may not be able to fully load some downstream links that have available capacity.

System Occupancy Adjustment (Sy OA). The *System Occupancy Adjustment* specifies the occupancy adjustment to upstream measurement for optimal downstream measurement control. *System Occupancy Adjustment* has a lower limit of -5% and an upper limit of 5%.

Optimal Occupancy (Opt O). The *Optimal Occupancy* specifies the optimal freeway system occupancy for downstream measurement control.

Sensitivity at Optimal Occupancy (Sen O). The *Sensitivity at Optimal Occupancy* specifies the rate of change of freeway flow per percent change in occupancy (dq/do) at the optimal downstream occupancy level.

The only fields in the Freeway Traffic Operations screen that can be set or modified by the user are the *Ramp Demand* and *Exit Flow* fields. The rest are either calculated by the User Interface Module or by the Optimization Module.

Commands

The user can also move to other screens by selecting one of the options displayed at the bottom of the Freeway Traffic Operations screen. The following options are available:

F1: Moves the user to the Freeway System Specifications screen;
F2: Moves the user to the Freeway System Parameters screen;
F6: Starts the Optimization Module;
F7: Starts the Local Ramp Metering (RAMBO I) Module;
F9: Displays a help screen that provides definitions for both the data elements and options that can be selected from the screen; and
F10: Allows the user to exit the system.

Selecting the **F6** or **F7** options will quit the User Interface Module and switch execution control to the Optimization Module or RAMBO I, respectively. However, when one of these modules finishes execution, control will be switched back to the User Interface Module. The three modules pass data to each other through external files. Batch files are used to transfer execution control from one module to another.

File Management Screen (F5)

The File Management screen provides the user with the basic file operations; loading an existing file, opening a new file, loading input data existing in the system before the user quit the previous session, and saving an input file for a freeway system. The screen consists of the options as illustrated in Figure 3.5.

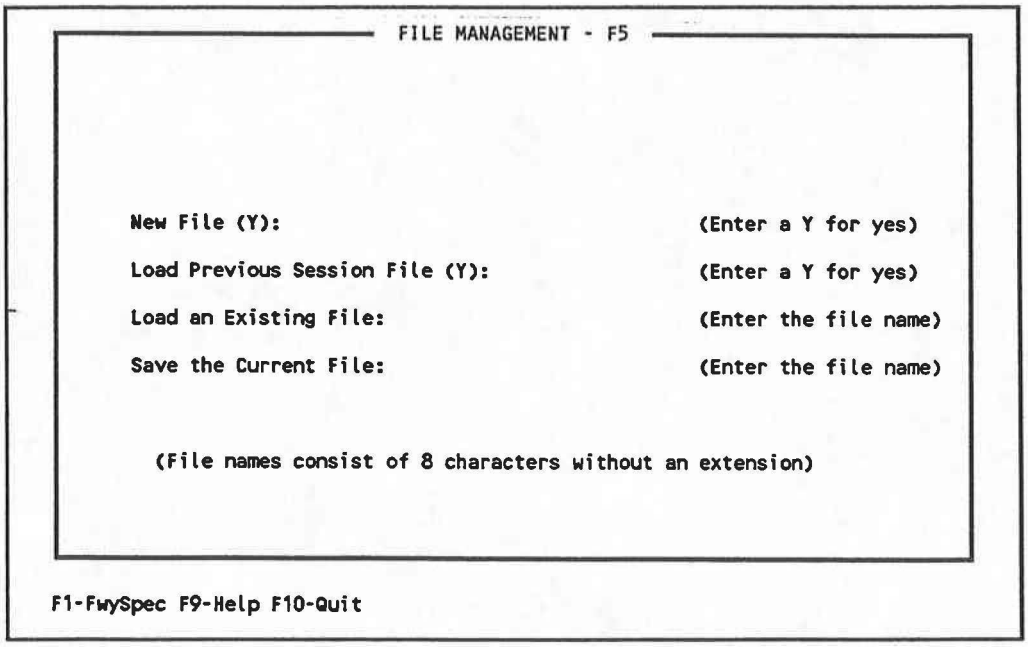

FIGURE 3.5. File Management Screen.

Data Entry Fields

New File. A new file can be opened by entering a "Y" at the *New File* prompt. Any character other than a "Y" will be considered an error. A new file will blank all the input data fields in screens **F1**, **F2**, **F3**, and **F4**. After the new data are entered, the user should save the new input file. If the user quits by mistake or intentionally before saving the new input file data, the information is automatically saved in a backup file called "rambo.bak". The user can restart the system and use the *Load Previous Session File* option in the File Management screen to restore the data from "rambo.bak" and save it to the desired filename.

Load Previous Session File. This option can be selected by entering a "Y" at the *Load Previous Session File* prompt. The data existing in the four screens of the User Interface Module, when the user quit the system the last time, will be restored. The system saves the data in the four screens into a backup file called "rambo.bak" anytime the user quits the system.

Load an Existing File. This option enables the user to load an existing file located in the same directory where the RAMBO II system is installed. The user enters the name of an existing input file without the extension at the *Load an Existing File* prompt. Input data files have an extension of ". int". The system will append a ".int" to the end of the file name entered and try to load the file. If the file doesn't exist, an error message will be displayed.

In this version, the system does not have the capability of displaying all the input files available in the current directory, although this feature will be included in a future version. Before starting the system, the user should use the DOS "dir" command to get a listing of all files with a ".int" extension in the RAMBO II directory. The input files are saved in the RAMBO II directory with a ".int" extension.

Save the Current File. This option will save the data from the four screens of the User Interface Module to a file. The file name is entered by the user without an extension at the prompt of *Save the Current File* field. The system will append a ".int" extension to the name of the file entered and save it in the RAMBO II directory. Before saving the file, the system will check if the file already exists, and prompt the user for overwriting the file or cancelling the operation. If an existing file was loaded and modified, the user must run the optimization module (option F6 in the Freeway Traffic Operations screen) before saving the file.

Commands

The user can also move to other screens by selecting one of the options displayed at the bottom of the File Management screen. The following options are available:

F1: Moves the user to the Freeway System Specifications screen;

F9: Displays a help screen that provides definitions for the available file management options; and

F10: Allows the user to exit the system.

Data Entry Procedure

When entering input data for a new RAMBO II file, the user should follow a certain order.

1. The data items in the Freeway System Specifications screen (F1) should be entered;
2. Then calibration factors in the Calibration Factors screen (F3) should be set;
3. The freeway parameters part of the input file in the Freeway System Parameters screen (F2) should be input; and
4. The demand and exit flow in the Freeway Traffic Operations screen can be input.

At this stage, the user can now run the Optimization Module from the Freeway Traffic Operation screen to analyze traffic operations within the freeway system. The user can go back and change values in other screens, but one should update values in other screens that are affected by the changes one made. The relationship between the different screens is explained in the various sections of the users manual wherever it is applicable.

OPTIMIZATION MODULE

The Optimization Module is the mathematical core of RAMBO II; however, the user never interacts with it directly. When the user selects the Run-F6 option in the Freeway

Traffic Operations screen, the User Interface Module writes the currently loaded data to a file and invokes the optimization routine. The optimization routine reads this data file and performs several functions in the order listed below.

1. A subset of the input data together with data embedded in the program is used to generate an origin-destination (OD) matrix.

2. The input data and the OD matrix is then used to set up the metering problem as a linear program.

3. The linear program is then optimized using a built-in optimization routine which determines optimal metering rates for all ramps and time slices. Detailed discussion of the linear program is provided by Messer *(2)*.

4. Results from the optimization routine are then translated into the final form.

5. Finally, control is passed back to the User Interface Module which displays all information it received from the Optimization Module.

LOCAL RAMP METERING (RAMBO I) MODULE

The RAMBO I module helps the user in preparing transition tables for TxDOT's ramp meters. It also assists the user in analyzing ramp metering plans for individual ramps. On the other hand, RAMBO II assists the user in achieving a system ramp metering plan. The RAMBO I module is run by selecting the Asst-F7 option in the Freeway Traffic Operations screen. For further details refer to Chapter 2 in this document entitled RAMBO I.

REFERENCES

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2. Messer, C. J. *Advanced Freeway System Ramp Metering Strategies for Texas.* Research Report 1232-23. Texas Transportation Institute, College Station, Texas. October 1993.

3. Chang, E. C. P., Messer, C. J., Wang, S. H., Huang, W., and Li, A. *Interim Program Documentation on System Ramp Control Optimization Algorithms.* Research Report 1232-25. Texas Transportation Institute, College Station, Texas. May 1994.