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16. Abstract

PASSER IV-94 is a new program for timing traffic signals in networks based on progression bandwidth optimization. This manual describes how to use the program to obtain optimal signal timings. PASSER IV is capable of optimizing signal timings for arterials as well as multi-arterial closed-loop networks. The program explicitly handles one-way and two-way arterials in a network and thus, is able to deal with conventional and three-level diamond interchanges in isolation or as sub-networks within a larger network of arterials. The program is composed of two modules: the user interface and the optimization module. The user interface is extremely easy to use and provides the following features: file management functions, data entry/edit modes, graphic display of network, running the optimization routine, and running the TRANSYT-7F program. In addition, it provides full mouse support. The optimization module performs bandwidth maximization. In addition to its own output report, the optimization routine is capable of generating input data files for use with the TRANSYT-7F program to perform bandwidth-constrained delay minimization. Thus, PASSER IV provides a network signal timing optimization capability that was previously available only for arterial problems through the combined use of the two programs PASSER II and AAP.

17. Key Words

Signalized Arterials, Signalized Networks,
Progression Bandwidth,
Signal Timing Optimization, PASSER IV-94

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PASSER IV - 94

Version 1.0

User/Reference Manual

by

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IMPLEMENTATION STATEMENT

The PASSER IV program developed in this study will be helpful to the Texas Department of Transportation traffic engineering professionals who plan, design, operate and maintain signalized - conventional and three-level - diamond interchanges. The program will be available to the Department personnel. The use of this program will enable the generation of signal timings to allow for the full utilization of interchange capacity and will result in reduced delay and fuel consumption. The program's use will also improve the efficiency of the state's traffic engineering professionals for solving network signal timing problems in their respective jurisdictions. The program is extremely efficient and easy to use, and will allow state personnel to analyze more alternatives in a shorter time than before.

DISCLAIMER

Progression Analysis and Signal Systems Evaluation Routine, PASSER, is a registered trademark of the Texas Transportation Institute (TTI), Texas A&M University System. As such, any use of this mark must have prior written approval from TTI.

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The program is distributed through McTrans Center at the University of Florida. Making copies of the program other than as specified in our end-user license is strictly prohibited. In addition, use of the program name and results in any published work must accompany proper reference to the program.

The users are advised to use this program at their own risk. TTI, THECB, TxDOT, FHWA, or McTrans are not liable for any damages (direct or indirect) resulting from the use of this program.

ACKNOWLEDGEMENT

PASSER IV is the result of several years of research funded by the Texas Higher Education Coordinating Board under the Energy Research in Application Program and by the Texas Department of Transportation, in cooperation with the Federal Highway Administration, under their Highway Planning and Research Program. We thank these agencies for their financial support.

Several individuals have made significant technical contributions throughout the development of PASSER IV. Ms. Anulark Pinnoi tested and implemented several heuristic optimization techniques and the methodology used to calculate tighter bounds on integer variables. Mr. Tai-Hsi Wu implemented and tested the TRANSYT-7F input data file generation routines. Mr. Rajivendra Nath developed the first working version of the user interface. Mr. Bogju Lee programmed several significant enhancements that led to the final version of the User Interface. Mr. Ali Haider Husaini developed and tested efficient data structures. Mr. Meher Malakapalli developed the delay estimation routine which was modified by Ms. Shireen Chada and incorporated into PASSER IV. Ms. Elizabeth Perez assisted throughout the development of this report. Mr. George Wier edited the final version of this report and prepared it for publication. All of these individuals worked for Texas Transportation Institute, Texas A&M University, College Station, Texas. Dr. Stephen L. Cohen of the Federal Highway Administration, Washington, D.C., provided several real-world network data sets that were used to extensively test the program. We thank all these individuals for their support in the development of PASSER IV.

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TRADEMARK INFORMATION

Progression Analysis and Signal Systems Evaluation Routine - **PASSER** - is a registered trademark of the Texas Transportation Institute, Texas A&M University System.

TRANSYT-7F was developed by the University of Florida in cooperation with the Federal Highway Administration.

Arterial Analysis Package (AAP) was developed by the University of Florida in cooperation with the Federal Highway Administration.

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SUMMARY

Traffic congestion on signalized arterials in large urban areas in Texas as well as other parts of the country costs million of dollars to travellers in terms of lost time and excessive fuel consumption, and also results in more air pollution. Further, the demand for increased capacity continues to grow rapidly, and this trend is expected to continue well beyond the turn of this century. However, because of budgetary and right-of way constraints, it is not always possible to construct or expand roadways to increase system throughput capacity. Even when it is feasible to increase roadway capacity through geometric improvements, this should not be done before ensuring that all available capacity is being utilized in the best manner. Optimizing signal timings to facilitate the flow of traffic on signalized arterials is a means of achieving this objective. Towards this goal, the Texas Department of Transportation has sponsored several research studies to develop and improve the tools for optimizing signal timings. PASSER IV-94 is the result of the latest study in this area. This report presents the User/Reference manual for PASSER IV.

PASSER IV is a personal-computer-based program for optimizing signal timings for signalized arterials and multi-arterial closed-loop networks. PASSER IV simultaneously optimizes progression bandwidth on all arterials in the network. It is extremely efficient, user friendly, and provides many features such as delay estimates, level-of service estimates, and a capability to produce alternate best solutions desired by the traffic engineering community. It is estimated that fuel savings in the six largest metropolitan areas in Texas from the use of PASSER IV-94 will be 0.45 million barrels of gasoline during the first year of use, with a total of 6.19 million barrels by the end of the century.

The User/Reference manual provided in this report is organized to facilitate ease of use for the novice as well as the experienced user. The manual consists of two major sections. The first section provides program information and explains important concepts. The second section provides a quick access reference guide. The Appendix provides information about some unique features in the program. An index is provided at the end to facilitate quick access to needed material.

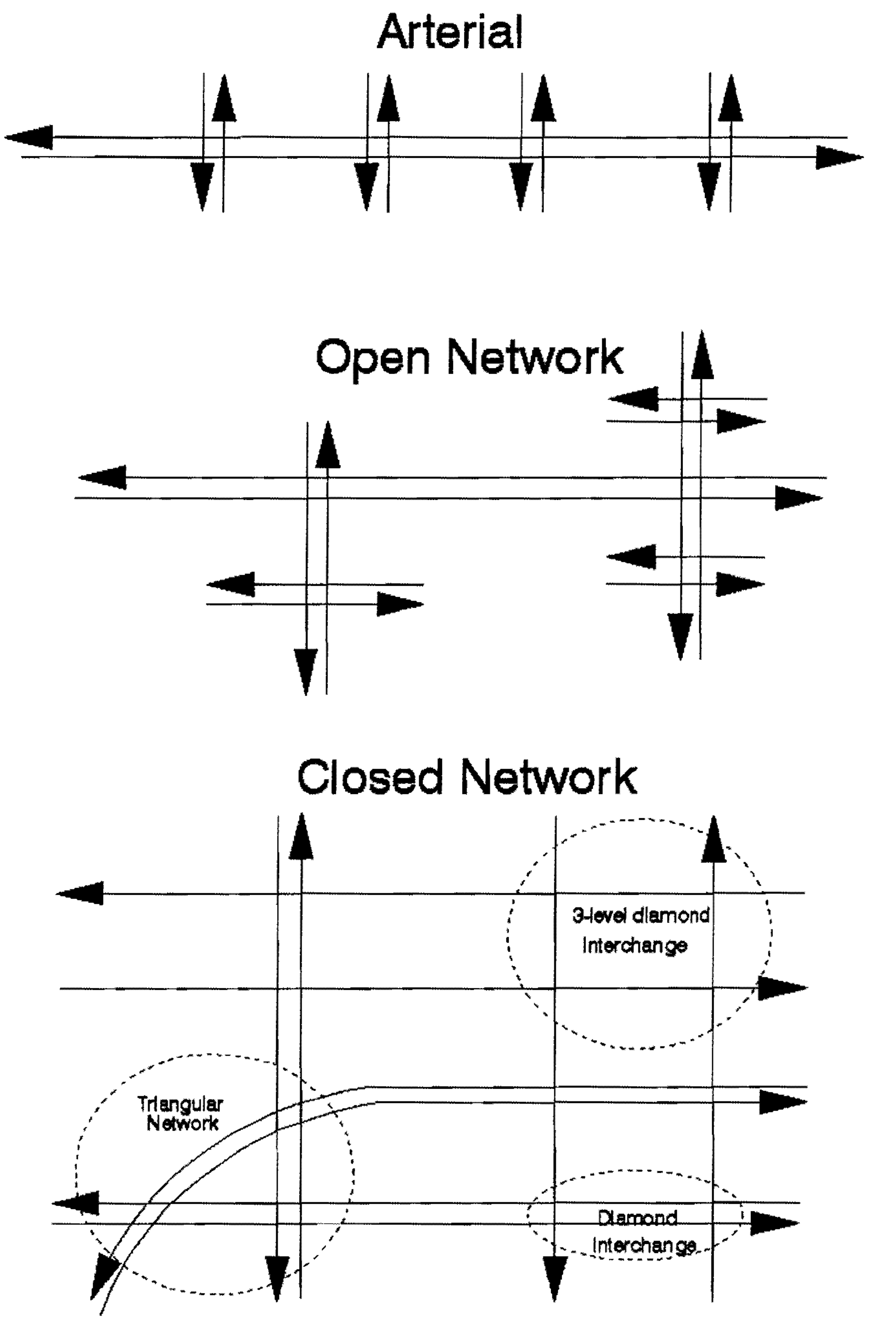
INTRODUCTION TO PASSER IV

PASSER IV is an advanced network traffic signal timing optimization program. It presently is the only practical personal computer (PC) program that can optimize signal timings based on maximizing platoon progression for large multi-arterial closed-loop networks. PASSER IV maximizes progression bandwidth on all arterials (one-way and two-way) in the network such as that shown in Figure 1. PASSER IV explicitly handles one-way arterials. The program is composed of two components: the User Interface, and the optimization core (routine), PASSR4. A batch file is used to control and link these two components. The description of each of these components is given in subsequent sections.

Program Features

PASSER IV is applicable to single arterials and multi-arterial (open or closed) networks. It determines the values of signal timing parameters that simultaneously maximize progression bandwidth on all directions along the arterials in the defined network. The key features of PASSER IV are described in the following:

1. Allows user-specified arterial and directional priorities.
2. Determines principal signal timing parameters:
   - Optimal cycle length,
   - Green splits using Webster's method,
   - Signal offsets, and
   - NEMA phasing sequences.
3. Allows link speeds to vary between user-specified limits, and constrains optimal speeds for adjacent links within specified limits.
4. Allows optional minimization of cycle length, given cycle length range and weight (importance) given to cycle length minimization.
5. Prints a specified number of best signal timing solutions.
6. Provides an optional search capability especially designed to generate multiple close-to-optimal solutions.


Arterial

Open Network

Closed Network

Figure 1: Potential applications of PASSER IV

7. Provides one global and two heuristic (2-step and 3-step) optimization procedures.

8. Prints an extensive output report that includes:

   - Input data summary,
   - Optimization performance plot,
   - Network signal timing summary,
   - Artery-by-artery signal timing sections including time-space diagrams, and
   - Signal-by-signal NEMA phasing tables and measures of effectiveness (MOEs), including: approach delays, volume-to-capacity ratios, and level of service.

9. Menu-Driven graphic user interface with pull down menus, mouse support, and a capability for using TRANSYT-7F program to fine-tune bandwidth-based signal timings to minimize network-wide delay.

Input Data

PASSER IV data input requirements are relatively simple as compared to other network optimization/simulation programs currently in use. The program data is divided into three categories described below:

Optimization Data and Run Options

This data is used for controlling the branch-and-bound optimization procedure. Detailed description of this data and related concepts are discussed in a later section entitled, "Optimization Data and Options, page 9."

Network Geometry and Movement Numbering Scheme

The data in this category is also referred to as static data. Once defined, these data remain unchanged for a given network. These data include approach link lengths. Other key elements in this category, and steps required for describing the network geometry and structure are to:

i. Assign a unique node identification (NODID) number to each signal.

ii. Assign NEMA phase 2 number to a selected signal approach. This selection can be different for each signal in the network.

iii. Optionally, assign a priority for each arterial. Arterial priority is a number between 1 and 100. A bigger number means a higher priority. A priority of 101 should be assigned if the priority is to be calculated using total volumes on the arterial.

iv. Assign an A-direction (principal direction) to each arterial. For a one-way arterial, A-direction should be the same as the traffic flow direction. For a two-way arterial the A-direction can be any one of the two flow directions. Assigning an A-direction does not imply that it is also the direction with higher volumes. The directional priority is specified separately.

v. Select the order in which arterials will be entered; that is, assign a sequence number to each arterial in the network. Enter each arterial in this order.

v. Starting from the first arterial, completely describe each arterial. Data for signals on an arterial must be supplied from the first signal to the last signal following the A-direction, without skipping any signals. Each signal is identified by its NODID which is also used to link the two arterials crossing at a signal.

This scheme implies all the necessary linkage information. The program is able to automatically construct the network structure by using NODID assigned to each signal.

Traffic Data

This data is also referred to as dynamic data. It describes the traffic conditions for a given analysis period. The data includes:

- Average speed and range of speed for approach links, and allowed speed variation for adjacent links,
- Optional queue clearance times at approaches,
- Traffic demand (volumes) at approaches,
- Saturation flow rates for approaches,
- Optional minimum green splits,
- Green splits (optional), and

- Cycle length range defined by lower and upper limits.

Computer Hardware Requirements

PASSER IV is developed for IBM PC and compatible computers. The program requires the following hardware and software.

- A PC with 640K of Random Access Memory (RAM). A minimum of 570K of RAM must be free for PASSER IV use.
- A hard disk drive with 1 megabyte of storage space available for permanent and temporary system files. Additional space is required for user (data and output) files. We recommend a hard disk drive with 10 or more megabytes of available space.
- A color monitor (optional).
- Microsoft or compatible mouse and mouse driver (optional).
- Standard DOS ansi.sys driver must be installed using the config.sys file. Refer to your DOS manual for details about DOS configuration.
- DOS should be able to open a minimum 10 files at a time. This is specified in the computer configuration file config.sys.

USER INTERFACE

The PASSER IV user interface (UI) is a complete network optimization environment that provides several useful features necessary for the efficient use of the optimization core routine, PASSR4. It enables the user to create input data files, execute PASSR4, and lets the user view and print output files. In addition, the UI provides a capability to execute the TRANSYT-7F program for fine-tuning bandwidth solutions to minimize system delay. TRANSYT-7F, however, must be purchased separately. The UI is developed using the Borland C^{++} programming language and the TCXL software package. Salient features of the UI include capabilities to:

- Create new PASSR4 data files,
- Modify existing PASSR4 data files,

- Delete user files,
- Run PASSR4,
- View and print PASSER IV output,
- Display the graph of the network defined in the loaded data file,
- Run T7F program,
- Edit T7F data, view/print corresponding output, and delete its files.

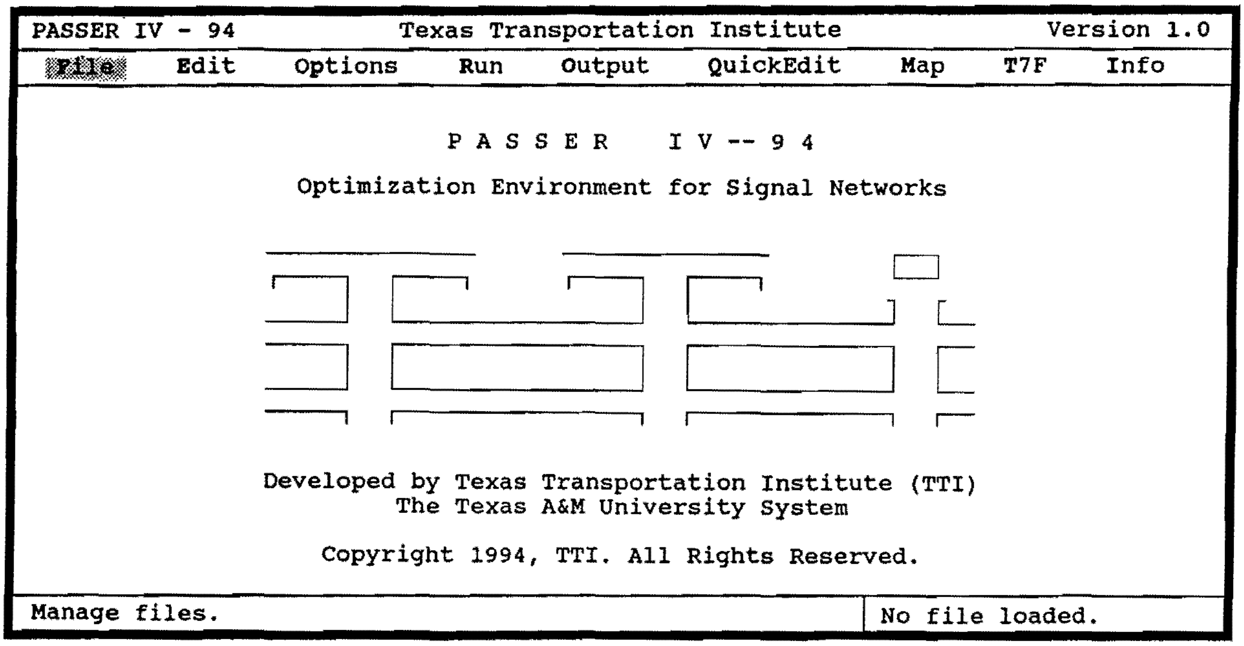
The PASSER IV User Interface is extremely easy to use with a minimum amount of practice. It provides keyboard as well as full mouse support. However, the mouse must be properly installed. Pressing the right button on the mouse is the same as pressing the <Esc> key on the keyboard.

The first screen you will see after invoking PASSER IV is the main screen of the UI. Figure 2 provides an illustration of this screen. The top line of this screen identifies the program name and its version, and the organization name that can be changed by the user using the Config option in the File menu. The second line on the screen displays the Main-Menu options. Items on the Main-Menu can be selected in several different ways:

- Moving the mouse cursor to the desired item and pressing the left button,
- Using left or right arrow keys to highlight a desired item and pressing the <Enter> key,
- Pressing highlighted letter (hot key) for the desired menu item, or
- Pressing the <Alt> key together with the highlighted letter of the menu item. This method can also be used to select a Main-Menu item from any sub-menu.

The bottom line, called the status line, provides brief context sensitive information about the item at the current cursor location, the name of the currently loaded file group, and the name extension(s) of existing PASSR4 file(s). More information about PASSER IV files is given in a subsequent section.

After a new data file is created, or an existing data file is loaded, the **Run** option performs the following two functions:



```
PASSER IV - 94            Texas Transportation Institute            Version 1.0
  File    Edit    Options    Run    Output    QuickEdit    Map    T7F    Info

                            P A S S E R   I V -- 9 4
                   Optimization Environment for Signal Networks

                 Developed by Texas Transportation Institute (TTI)
                          The Texas A&M University System

                     Copyright 1994, TTI. All Rights Reserved.
Manage files.                                          No file loaded.
```

Figure 2: PASSER IV main screen

- If necessary, lets the user save modifications on the data file, and
- Executes optimization routine, PASSR4.

Upon termination of PASSR4, control passes back to the UI and the cursor is placed at the **Output** option of the Main-Menu.

OPTIMIZATION ROUTINE

PASSR4, the main core of PASSER IV, is an independent program which can be used to optimize signal timing optimization problems even when the UI is not available. This will allow incorporation of PASSR4 in existing traffic management systems and future IVHS systems. PASSR4 reads the data from a data file (created using the UI or any general purpose text editor), and generates an output file containing the summary of input data and/or optimal signal timing report containing the best signal timings. It can handle networks with up to 20 arterials and a maximum of 35 intersections. An arterial in the network can have up to 20 intersections. Potential applications of PASSER IV include: signalized arterials, conventional diamond interchanges, three-level diamond interchanges, and downtown grid networks with one-way and two-way arterials.

In addition to its main feature, progression bandwidth optimization, PASSR4 is also equipped with the capability to facilitate bandwidth-constrained delay optimization. This optional feature in PASSR4 allows generation of input data files for T7F, which can then be used to either evaluate or fine-tune a PASSER IV solution using the T7F program. A PASSR4 generated input data file for T7F is composed of user supplied data and PASSR4 best signal timings as the starting solution. As noted earlier, the UI provides capabilities to edit T7F data file(s), run T7F, view/print T7F output, and delete related files.

PASSR4 is written in FORTRAN 77 and is portable to computers other than PC's. It is composed of several sub-modules combined to form a single executable program. The MAIN program controls all sub-modules. Each of the sub-modules is described in the following paragraphs.

The INPUT module reads data from the specified input data file. It then checks data for errors, prints warning and error messages, makes necessary computations (such a green split calculation), and generates a file containing the mathematical programming formulation of the current problem. Process control is then passed to the optimization module.

The mathematical programming formulation is read and optimized by the MPCODE module, which is an independent optimization program. MPCODE is capable of saving multiple feasible solutions. At the successful termination of MPCODE, control is passed back to the MAIN program.

The Main program then activates the OUTPUT module which generates the PASSR4 output report. The output report may contain the input data summary and the best signal timing report corresponding to each saved solution. A signal timing report contains: system-wide bandwidth summary, a section devoted to signal timings for each arterial, and summary of signal timings and measures of effectiveness for each signal. At the user's option, it also generates input data file(s) for use with T7F.

OPTIMIZATION DATA AND OPTIONS

Optimization data is entered from the Main-Menu by selecting the **O**ptions item. This section explains concepts related to data used by MPCODE, the PASSR4 optimization module. The novice may wish to scan through this section during the first pass. It is recommended that the user attempt to understand the concepts after some experience with the program, since a better understanding of the following concepts will enable a more efficient use of the program. A sincere effort is made to keep the presentation as simple as possible.

PASSR4 sets up and solves a given traffic signal synchronization problem as a formal mathematical program with all its attendant strengths and weaknesses. This program, or mathematical formulation, is called a mixed-integer linear program (MILP). The remainder of this section provides general information that is intended to familiarize the user with important concepts necessary for the utilization of MILP in PASSER IV.

Any optimization problem, written in a mathematical form, has an objective function that is to be optimized. Within the current context, the program objective is to maximize the sum of arterial bandwidth efficiencies. Thus, the objective function describes the objective in a mathematical form using variables to represent efficiencies and corresponding coefficients to indicate directional priorities. Further, the optimization problems have constraints that keep the variables (cycle length, offsets, speeds, etc.) within proper bounds. A pure linear program (LP) results when all variables are continuous and when the objective function and constraints are linear. Cycle length and travel speeds are examples of continuous variables. When a subset of variables is restricted to integer values, the LP becomes an MILP. While, optimizing an LP problem is a relatively trivial task, optimizing an MILP problem requires tremendous computational effort.

In any signal synchronization (bandwidth maximization or delay minimization) problem, three types of variables must be restricted to integer values. These are described below:

Link synchronization

This ensures that the sum of offsets for a pair of links connecting two signals is equal to an integer number of signal cycles. These constraints result in (unrestricted) integer variables that can be either negative or positive.

Network synchronization

This ensures that the sum of offsets for all arterials forming a closed network loop is equal to an integer number of cycles. These constraints also produce unrestricted integer variables.

Phase sequence selection

On two opposing arterial approaches to an intersection, a maximum of four alternate phasing sequences may be possible. These are: lead-lag, lag-lead, lead-lead, and lag-lag. Thus, a set of two binary variables is needed to distinguish between these possibilities. Binary variables are integer variables that can only be either zero or one.

MPCODE uses a branch-and-bound (BB) technique to optimize the MILP problems generated by PASSR4. The BB techniques create a decision tree and make use of an LP algorithm, such as the Simplex method, for solving the Linear Program (LP) sub-problems. The end of a branch on the decision tree represents a feasible integer solution for the current problem. The BB algorithm is designed to only search a fraction of all the possible branches. The BB algorithm starts by solving an LP obtained by relaxing all integrality constraints in the MILP. This gives an upper bound (target value) on the best solution. The BB then proceeds by systematically partitioning the solution space using variables which are required to be integer, but have non-integer values. A restricted LP is solved at each branch. A branch reaches its end when all integer variables have attained integer values. A branch satisfying all MILP constraints determines the current best solution. Other branches are then pursued to determine a better feasible solution. During the optimization process, the target value may be revised. The BB algorithm terminates when an integer solution attains the target value or when all possible branches have been searched.

In the following discussion, we describe some terminology that the user will need to know to efficiently use PASSER IV. The sub-sections are divided by data categories to make the use of each data type easier to understand.

Upper Limit on Iterations

A set of LP calculations is called an iteration. Depending on the size of an LP (total number of variables and constraints), an iteration will require a different amount of computation time (for example, one iteration for a single arterial problem will take much less time than one iteration for a multiple arterial network problem). MPCODE keeps track of the maximum number of iterations required by an LP sub-problem. It also keeps track of the total number (sum) of these iterations, referred to as BB iterations. Normally, the number of iterations required by an LP can be well-predicted given the known size of the LP. Too many LP iterations beyond a predicted number is indicative of a cycling problem that arises when an LP fails to terminate due to data errors in the problem. The upper limit on LP iterations is used in MPCODE to protect against such cycling problems, which may cause the LP algorithm to switch back and forth between two feasible solutions without terminating. Thus, if an LP exceeds the user-selected upper limit on LP iterations, the optimization algorithm terminates. Further, experience with many bandwidth-based problems has shown that very good solutions may be found fairly quickly, but the BB algorithm may require a significant number of additional iterations to complete the search process. This happens, particularly, in those cases when the sum of bandwidth efficiencies for the current best solution are much less than the target value. The upper limit on BB iterations is used to control how much time the computer can use to generate a good solution. When the user-specified upper limit on BB iterations is reached, the program terminates and prints the best solution, if any, found thus far in the optimization process.

Upper Limit on Re-inversions

At the end of an LP iteration, certain known columns of the problem matrix must have values of either 0 or 1. Due to round-off errors in computer calculations, however, values other than 0 or 1 may result in some of these columns. If left uncorrected, these will result in incorrect solutions. Re-inversion is a process of correcting round-off errors by placing correct values in the right places whenever the errors increase beyond a certain limit. However, the need to perform re-inversions beyond a reasonable limit is indicative of problems with the data and should not be allowed. PASSR4 keeps track of the maximum re-inversion required by an LP as well as the total re-inversions for the current optimization run. If any one of these numbers exceeds the user-specified limits, the run terminates.

Restarting the BB Algorithm

When the BB algorithm terminates prematurely due to the user-specified limit on iterations or re-inversions, a Restart file is produced that can be used to restart the search process from where it stopped. This is done by setting the Restart flag to "yes"and running the program again. Note, however, that for two-step and three-step heuristic optimization methods, only the first step of the optimization process can be restarted. Selection of the optimization steps is discussed below.

Printing Optimization Performance Plot

Selecting this flag as "yes" causes the optimization process to print the value of the current best solution and the corresponding number of BB iterations whenever a new feasible solution is found and selected as the current best. This printing capability is used for monitoring the optimization process. However, this capability works properly only when the standard DOS device driver ansi.sys has been installed using the config.sys file.

Minimizing Cycle Length

Selecting the cycle length minimization flag to "yes" causes the program to add the inverse of cycle length (Z) to the objective function. Note that maximizing Z is the same as minimizing the cycle length. The objective function weight can be specified by the user to indicate the importance of cycle length minimization. This will cause generation of the lowest cycle length solution with the best bandwidth efficiency. This facility is useful when multiple solutions, having the same bandwidth efficiency but different cycle lengths, exist. In other cases, especially when a higher value of weight is used, the algorithm may produce a sub-optimal progression solution. This facility can be used to generate alternate signal-timing solutions.

In-depth Search

The selection of this flag increases the chance of generating the best possible solution when heuristic optimization procedures are used. This advanced capability modifies the normal decision process of the BB algorithm and will generally require more central processing unit (CPU) time. It is intended for use by advanced users and for research purposes, where long run times are not so critical.

Optimization Procedure

As discussed at the beginning of this section, there are three possible types of integer variables in a signal timing optimization problem: a link synchronization variable for every two-way link, a network synchronization variable for each closed loop in the network, and a binary variable for each protected phase. PASSR4 is capable of exploiting the nature of these variables to increase its computational efficiency. The program provides three optimization options. A description of each of these options along with its applicability is given below:

Global or Simultaneous (1-Step) Optimization

Global optimization is selected by setting the number of optimization steps equal to 1. If this option is selected, all variables are simultaneously optimized. This procedure is applicable to all types of arterial and network problems. Given a large enough limit on iterations and re-inversions, this process will ultimately produce the best possible signal timings. However, it may require an enormous amount of central processing unit (CPU) time. Therefore, this method is not generally recommended for routine use.

Two-Step Heuristic Optimization

The Two-Step optimization procedure, selected by setting the number of optimization steps equal to 2, works as follows. In the first step, it finds the best link and/or network synchronization. It then automatically fixes all synchronization and finds the best phasing sequences. If this option is selected and there are no phasing sequences to be optimized (either no phases or all phases are optimum at the end of step 1), the algorithm terminates at the end of the first step. This 2-step method is ten times faster than the global optimization method. In addition, it will very likely result in the best possible solution. This method is applicable to all problems other than those with only one-way arterials (such as signalized three-level or split diamond interchanges). The possibility of generating the best solution can be increased by requesting the program to save multiple solutions from the first optimization step. When multiple solutions are saved in the first optimization step, the second step is repeated for each saved solution and the solution with the best total bandwidth is automatically selected as the final solution. This selection will also increase the CPU time since more sub-problems are solved at the second step.

Three-Step Heuristic Optimization

The Three-Step optimization procedure, selected by choosing the number of optimization steps equal to 3, works as follows. Best link synchronizations are determined in the first optimization step. Using the best link synchronization solution from step 1, network synchronizations are determined in the second optimization step. The third step uses the best link and network synchronizations to determine the phasing sequences. This method is applicable to all multi-arterial closed loop networks with at least one two-way arterial and some left-turn phases. When applicable, this is the fastest method to obtain very good solutions. As compared to the global optimization method, it is up to 99% faster. The solutions generated are not necessarily the best possible. However, considering the fact that the input data is never 100% accurate or up-to-date, this procedure provides good solutions for most problems. The possibility of obtaining close to the best solution can be increased by requesting the program to save multiple solutions at steps 1 and 2. Thus, the second and third steps will be repeated for each best solution from the previous step. This will also increase the CPU time, depending on how many times these steps are repeated.

It is recommended that the number of steps (optimization procedure) selected for a given problem be the highest number possible, say 3-step, since this selection will require the least amount of CPU time. For example, the 3-step optimization procedure is recommended for multi-arterial closed networks with multi-phase signals. The last step of the two heuristic optimization methods, that is, the phase sequence optimization, requires the least amount of CPU time. Therefore, requesting multiple solutions at the first step of the 2-step method and only for the second step of the 3-step method is recommended since this procedure will increase the chances of finding good solutions with very little additional computational burden.

Obtaining Multiple Best Solutions

Our experience with bandwidth optimization problems, especially multi-arterial networks, has shown that these problems generally have multiple, sometimes dozens of, feasible solutions. In addition, a number of alternate solutions may have progression bands that are either very close to the best solution, or the same as the best solution. This may happen for several reasons:

- Solutions with different cycle lengths, but the same bandwidth efficiency, may exist.
- For an arterial, an alternate solution may be the result of a different offset at any one of the non-critical intersections.
- For a network, an alternate solution may be the result of a different allocation of maximum bandwidth efficiency between various arterials. For example, the total network efficiency may be kept unchanged by taking some band away from an arterial and by increasing the band on another arterial by the same amount.

We conducted an extensive analysis of system-wide delay and fuel consumption using multiple solutions for a number of real problems. We discovered that solutions having no significant difference in total bandwidth efficiency had very different delay and fuel consumption estimates. At the end of this study, we concluded that these measures of effectiveness can be used to determine which of the alternate bandwidth solutions should be selected for implementation.

In order to facilitate further analysis, PASSR4 was programmed to enable reporting of signal timings for a specified number of multiple solutions. This is done by requesting multiple solutions for the last step of the selected optimization process. For example, to obtain three best solutions from the 3-step method, use 3 for the solutions to be saved in the third step. When the actual number of solutions found is less than that requested by the user, reports will be generated for only the best solutions found. Thus, if the user requested four solutions and only two best solutions are found, the program will print only two solution reports.

Tolerances

As noted earlier, computer calculations usually result in round-off errors. The purpose of a tolerance is to compare a pair of numbers to determine whether they should be treated equal. For example, a tolerance of 0.001 will treat two numbers the same if their absolute difference is less than this number. Tolerances 1 to 7 are used for comparing the values of seven important variables encountered during the MILP optimization process. The capability to select these values is provided for advanced users. For common use, however, three sets of tolerances are pre-defined in the configuration file. Any one of these pre-defined sets can be retrieved using the <F1> key as described in the Reference section. In general, however, selecting too small a value indicates the need for higher accuracy resulting in excessive CPU time. Further, very small values of these tolerances may terminate the algorithm with an infeasible solution. On the other hand, large values may terminate the algorithm with a non-optimal solution. TOLF, the last of the tolerances, is used to accept or reject the next feasible solution found and to determine if a branch is to be further analyzed. A value of 0.01,for example, will cause the program to accept the next solution only if it is 1% better than the current best solution. Thus, the judicious selection of TOLF can be used to speed up the search process. However, a larger value for this tolerance may cause the solution to terminate before reaching the best optimal solution.

Imbedded MPCODE Data

PASSER IV uses default values for all MPCODE data. In most cases, these default values will be sufficient. The following is a list of data items that may be required to change on a regular basis:

- Upper limit on BB iterations,
- Selection of optimization process (1-step, 2-step, or 3-step), and
- Number of solutions to be saved for each step.

FILE NAMES AND CONVENTIONS

There are two types of files the user must know about in order to properly use PASSER IV. These files are referred to as system files and user files. A list of existing user files can be viewed using the **Open** option from the **File** menu. The following is a description of files in these two categories.

System Files

System files are defined to be those permanent files that comprise the PASSER IV program and those temporary files that are created and used by the program during its operations. The names of these files are reserved and should not be used for user files. The following is a description of these system files:

p4config.sys — PASSER IV configuration file. This file contains user modifiable data and is used by the UI. It contains the default path to locate user files, user organization name, a path to locate T7F, and three sets of pre-specified tolerances that can be selected from the **Options** item of the Main-Menu.

p4menu.exe — This executable file is the User Interface, UI.

p4menu.msg — System file used by the UI.

passr4.exe — PASSER IV optimization routine. This routine can also be used at the DOS prompt by typing the following command:

```
passr4 filename1 filename2
```

where, *filename1* is the name of a PASSR4 input data file, and *filename2* is the output file generated by PASSR4. The input and output file names can be any valid DOS name, including any DOS extensions.

pasfile — File used by passr4.exe (PASSR4) for intermediate data transfer between its various modules. It is deleted at the end of a PASSR4 run.

p4.bat — Batch file used to control the execution of PASSER IV. This file passes control back and forth between the UI, PASSR4 and T7F (when applicable).

mpcode.dat* MPCODE data files generated by PASSR4. This file contains the MILP formulation for an optimization step represented by the *. These files are deleted at the end of each run.

mpcode.out* Output file generated by MPCODE. One file is generated at each optimization step. These files are deleted at the end of each run.

restart.out Output file generated by MPCODE for use in restarting or continuing the optimization process. If PASSR4 is used from DOS, this file should be renamed to "restart.dat" before restarting.

User Files

A user file group contains the data file that is created by the user and those files that are created by the program for their use. User files are identified by a user-specified name, called a *groupname*, which is composed of up to 8 alphanumeric characters following the same convention as DOS file names. It is recommended that a separate data directory be provided for these files. A user defined *groupname* may include several files, each identified by a different DOS extension attached to it by the UI. When a group name is selected, all files with that group are said to be active and can be accessed by choosing the applicable options from the Main-Menu. These files include:

groupname.dat PASSR4 input data file created by the user. A new data file can be created using the **New** option from the **File** menu. The data file in the currently loaded group can be modified by selecting either **Edit**, **QuickEdit**, or the **Map** option from the Main-Menu, and can be deleted using the **Delete** option from the **File** menu. In addition, a data file can be renamed by using the SaveAs option in the **File** menu. When this option is used, the UI assumes the renamed group as the current work group. At this time, however, the new group only consists of the data file.

groupname.out This file is generated when the **Run** option is selected from the UI. Selecting the **Output** option from the UI allows the user to view and/or print sections of the output file in the currently loaded group. An output file can be deleted using the **Delete** option in the **File** menu.

*groupname.ti**

At the user's option, these files are generated by PASSR4. These are input data files for performing bandwidth-constrained delay optimization using the T7F (TRANSYT-7F) program. One data file is generated for each solution reported in the PASSR4 output file *groupname.out*. The * represents the solution number. This file is created using the data from the data file (*groupname.dat*) and a set of signal timings, including corresponding bandwidth constraints. These files can be deleted from T7F menu using the 'Delete File' option.

*groupname.to**

These files are generated by running T7F by selecting the **T7F** option from the Main-Menu. For example, running T7F using the file *groupname.ti1* will generate an output file named *groupname.to1*. The **T7F** sub-menu also lets the user view and print these files. In addition, these files can be deleted using the T7F sub-menu.

DATA ENTRY PROCEDURES

An arterial in the network can be entered in any order (the program attaches a sequence number to each arterial in the order it is entered). However, signal data within an arterial must be entered starting from the first intersection and proceeding to the last intersection following in the A-Direction, without skipping any signal. In addition, each signal must be assigned a unique node identification number which is used by the program to find linkages in the network. The data for an intersection falling on two arteries needs to be entered only once. For example, if signal 1 on arterial 2 and signal 3 on arterial 5 have the same node identification number, the data for that signal should be entered only once.

The above format is slightly restrictive as compared to some network programs available to the traffic community. However, it is also very simple, since the data entry sequence informs the program about the linkage of signals, which the user has no need to provide.

PROGRAM INSTALLATION

PASSER IV requires a minimum of 570K of free RAM for running. It also requires the standard ansi.sys driver that comes with DOS. If not already installed, the ansi.sys driver can be installed by adding the following line to the config.sys file in the root (C:\) directory of your hard disk drive:

device=path\ansi.sys

where, *path* describes the directory where the driver file (*ansi.sys*) is stored.

In addition, the computer system file should be set such that at least 10 files can be opened at a time. This can be done by adding the following line to the config.sys file:

files=10 (or more)

PASSER IV installation is straightforward. The program installation process requires the following steps:

1. Deciding where to store the system files. For example, directory C:\P4.

2. Creating the system directory (i.e.,C:\P4), and copying the system files to that directory.

3. Deciding the name of the default data directory and creating that directory. For example, C:\P4\DATA.

4. Creating or modifying the system configuration file (*p4config.sys*). This can be done by choosing the Config option from the File menu. Among other settings, this file tells the UI the path of the working directory.

Although PASSER IV can be installed with any user defined configuration, it is strongly recommended that the data directory specified be a sub-directory of the system directory. This will make it easy to keep track of PASSER IV related files.

Install Program

An install program (file *install.exe*) is supplied on the distribution diskette. This easy-to-use program performs the following functions:

- Allows the user to specify the names of system and data directories,

- If necessary, creates the specified directories,

- Copies system files to the system directory,

- Copies sample user files to the data directory,

- Modifies the PASSER IV config file (*p4config.sys*) as needed, and

- Checks the computer configuration (*config.sys*) file and gives a message if the *ansi.sys* driver is not installed.

Note: The path for T7F is left blank. The proper path must be specified by the user in order to use the T7F menu. This can be done by selecting the Config option from the PASSER IV **File** menu.

To use the installation program, insert the distribution diskette in the appropriate drive (i.e, *B*) and then go through the following steps.

1. From the hard disk prompt type, *B:\install* and press the <Return> key, or, change the default drive to that containing the distribution diskette and type, *install* and press the <Return> key.

2. Use the screen to enter desired directory specifications. The installation program can be aborted by pressing the <Esc> key.

RUNNING THE PROGRAM

To run PASSER IV, follow the steps given below:

1. Change the default directory to the system directory. For example, if the system files are stored in directory C:\P4, type the following line at the DOS prompt:

   CD C:\p4

2. To run PASSER IV, type the following line at the DOS prompt:

   P4 <Return>

The program should begin to run. Good Luck!

BASICS FOR USING PASSER IV

The previous sections described PASSER IV (explaining what it does and how it works). This section reiterates some of the things previously described and gives a step-by-step guide for using the program in an efficient manner. It is recommended that users first make themselves familiar with the UI by using the sample files provided with the program. A listing of existing files in the default data directory can be viewed by choosing the **Open** option from the File sub-menu. In the following, we describe how the user should then proceed in order to efficiently create new data files and run the optimization routine.

Data Preparation, Planning, and Organization

This stage starts with the need to use PASSER IV for obtaining signal timings for either an existing system or for a future system. The user is encouraged to peruse the following steps.

1. Define the limits and size of the system to be synchronized. This includes the number of arterials and signals in the system.

2. Draw a graph of the network. A graph is a map showing how the arterials and signals in the system are connected. This map is not necessarily drawn to scale like a real map. Figure 3 shows the graph of a 9 arterial by 18 signalized intersection network. Put the following information on the graph.

   i. Node identification number (maximum three digits) for each signal. The choice is arbitrary; however, each signal must be assigned a unique number. In Figure 3, a node is represented by a circle containing the node number.

   ii. Assign a sequence number to each arterial in the order you wish to enter data for each arterial (this step does not apply if your system has only one arterial).

   iii. For each arterial, label the A-direction using arrow heads. A-direction is used to distinguish between the two arterial directions and dictates how data is to be entered. A-direction is not necessarily the direction with major traffic flow. The directional priority is used for this purpose and is entered separately. For a one-way street, however, the direction of traffic flow should be the A-direction. In Figure 3, the arrowheads point toward the A-direction. For example, A-direction for Artery 6 (A6) is northbound. The signals on this artery will be entered in the sequence 56, 57, and then 47.

   iv. Optionally, add link lengths and other approach data on the graph. The approach data includes:

      Peak hour volumes

      Saturation flow rates (these must be calculated or estimated before using PASSER IV).

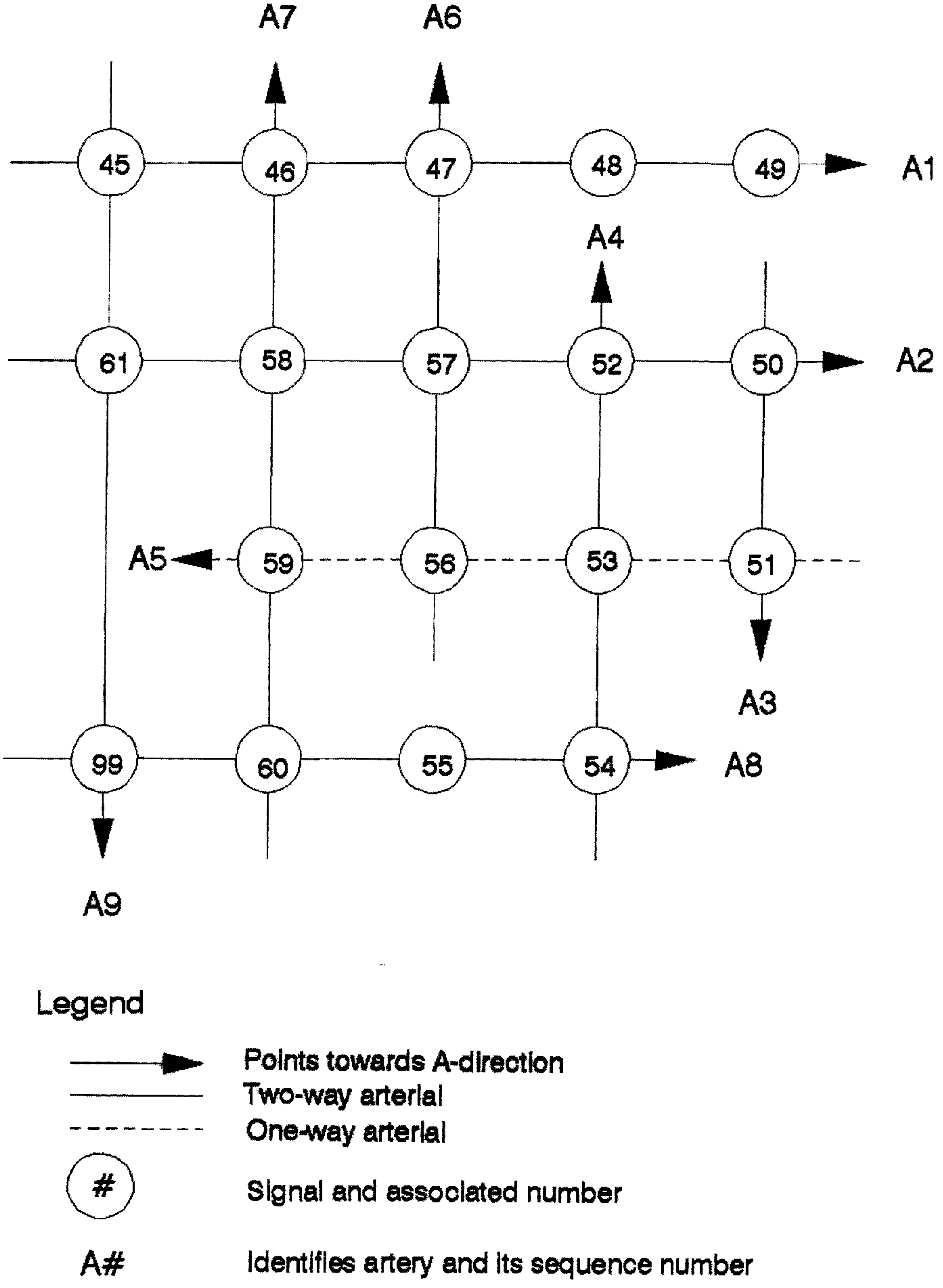

A7
A6
45
46
47
48
49
A1
A4
61
58
57
52
50
A2
A5
59
56
53
51
A3
99
60
55
54
A8
A9
Legend
Points towards A-direction
Two-way arterial
One-way arterial
#
Signal and associated number
A#
Identifies artery and its sequence number

Figure 3: Graph of a sample network

Minimum splits based on external factors such as pedestrian requirements.

Optional green splits. Normally, the program calculates splits using volume and saturation flow data. If green splits are provided, the program uses the supplied splits. The splits can be supplied in seconds or fractions of a cycle.

Average speeds on, and allowed speed variation between, approach links.

Allowed phasing sequences, if any. For minor cross streets, only one phasing sequence can be selected. A minor street is a street at a signal on which the band is not being optimized. For example, in Figure 3, the fourth signal (node number 48) on artery 1 (A1) has a minor cross street. Figure 4 shows the four possible phasing sequences for an artery.

3. Use the **New** option from the **File** menu to select a *groupname*. This automatically executes the **Edit** option from the Main-Menu.

Initial Data Entry

When the **Edit** function is selected from the Main-Menu, the System Data Screen is displayed. This is the top-most data entry level. The **Edit** mode is exited by pressing the <Esc> key from this level. Other data entry levels can be accessed using the <F3>, <F2>,<PgDn>, and <PgUp> keys. Once on any data screen, the skeleton data must be entered. This data is the minimum amount of data that is required to define the network structure. An efficient way of entering new data is to first enter all skeleton data and then enter the remaining data. The steps required to enter new data are as follows:

1. System Data Screen lets you enter systemwide data. The skeleton data for this screen includes the number of arterials and signals in the network.

2. From the System Screen, pressing the <F3> key will take you to the arterial level starting with the first artery. The skeleton data for an Artery Screen includes the number of intersections on that artery, and the A-direction for that artery. At an artery screen, you can use the <PgDn> or <PgUp> keys to move to the data entry screen for another arterial in the network. Pressing the <F2> key will move you back to the System level.

3. From an Artery Screen, pressing the <F3>key will move you to the signal level for that artery, starting at the first signal. At the signal level, <PgDn> or <PgUp> keys can be used to switch to the next or previous signal data screen. The skeleton data for a

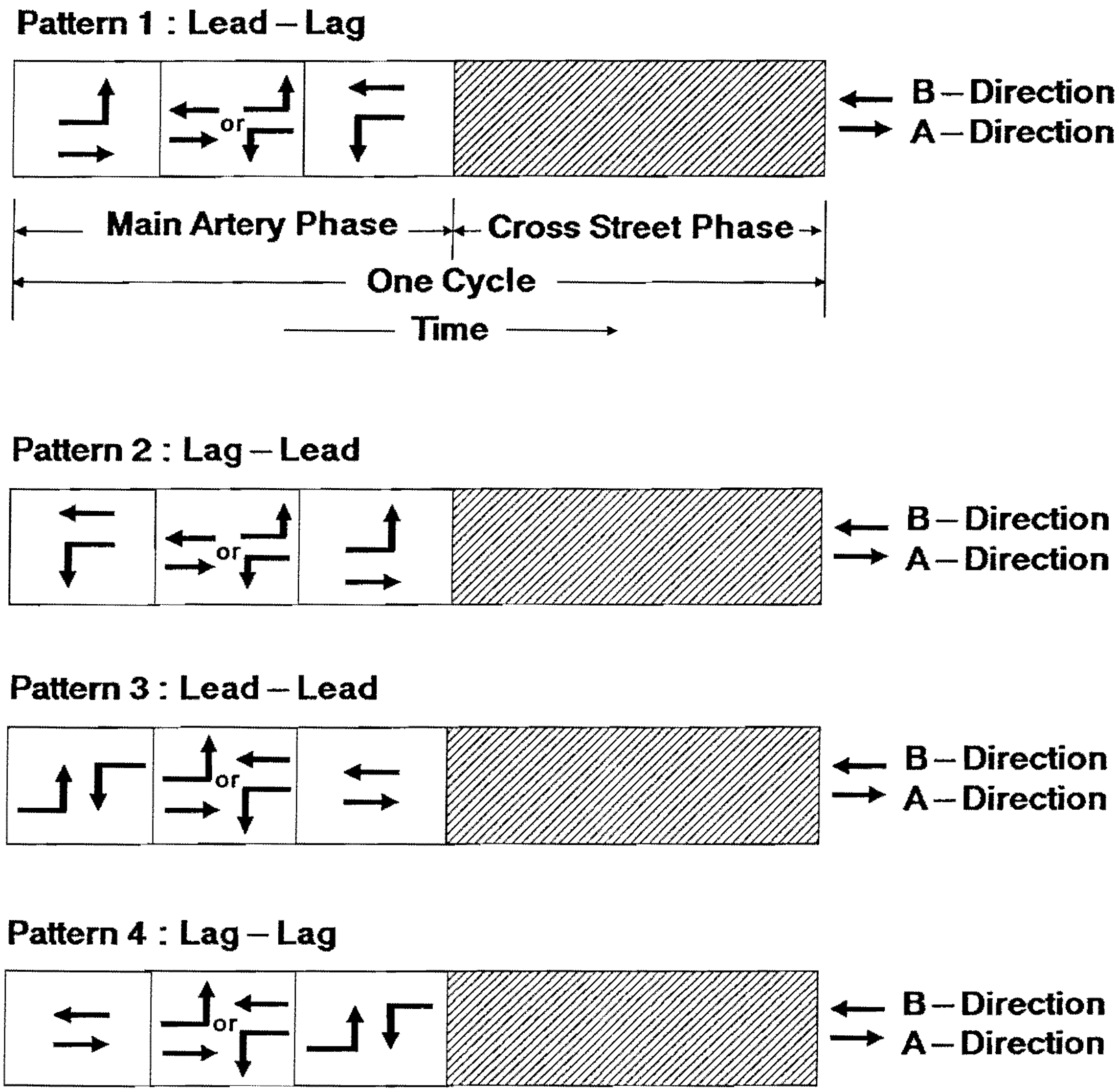


Figure 4: Four possible NEMA phase sequences

signal screen is the node identification number. At any Signal Screen, the <F3>key can be used to display the pop-up window for entering the phasing sequence selections for that signal. Pressing the <F2>key will move you one level up from the current level. Note that the data for all signals on an arterial must be entered in sequential order along the A-direction.

Data Modification

Once the skeleton data has been entered, the user can easily modify or add the remaining data by moving to any data entry screen. At this stage, three options are available to the user.

1. Use the **Edit** option from the Main-Menu as described in the previous section.

2. Use the **Map** option from the Main-Menu. When this option is selected, the UI draws a map of the network. The skeleton data must be present in order to draw the correct map. From the map screen, the mouse button or arrow key can be used to go to any data entry field. The <Esc> key brings you back to the map screen. Use a sample data set to experiment with this user-friendly capability.

3. Use the **QuickEdit** option from the Main-Menu. This option allows the user to directly edit the sequential data file (*groupname.dat*). For details regarding the structure of this file, see the Reference Section of this manual. This capability is useful for modifying the skeleton data. With a limited knowledge of the structure of this file, you can easily add to and/or delete arterials and intersections from the current data.

Running the Optimization Routine

After the data entry is complete, choose the **Run** option from the Main-Menu. Invoking this option will perform the following functions:

1. Preliminary data checking and, if necessary, giving an option to save modifications.

2. Passing control to PASSR4. This is done by exiting the UI. The main screen, however, is not cleared. At the user's option, the status of the optimization process is printed at the bottom of the screen without scrolling the lines. This only works properly if your computer system is configured as described earlier. If your screen starts to scroll, it is an indications that your system configuration file (*ansi.sys*) is not properly installed. In that case refer to the PASSER IV Installation section. This, however, will not affect the optimization results.

3. When PASSR4 ends, the control is passed back to the UI and the cursor is placed at the **Output** option of the Main-Menu.

Output

To view and/or print the PASSER IV output file (*groupname.out*), select the **Output** options from the Main-Menu. Invoking this option loads the output file. Several functions are available to allow you to view or print this file. See the Reference section for complete details.

Depending on user selected options, the PASSER IV output file may contain several sections. The following is a description of these sections:

Input Data Summary

PASSR4 checks input data whenever it is run. The summary of input data and results of calculations (i.e. determination of splits) done in the pre-processor are only printed if desired by the user and when there are no fatal errors in the data. The summary section includes:

- Contents of the input data file (*groupname.dat*),
- Options selected or assumed for use with the optimization program MPCODE,
- System data summary including a description of closed loops detected in the network, and
- A summary of data entered for each arterial in the network.

Warning Messages

At the user's option, warning messages are printed. A warning message is generated when data has errors that can be corrected using predefined default values.

Error Messages

A message is printed corresponding to each error detected. In case of errors, the program attempts to proceed as far as possible. Each error message is self-explanatory.

Optimization Performance Plot

When PASSR4 performs a signal timing optimization, it optionally prints the status of the optimization process. If requested, this section follows the Input Data Summary section. The information for each optimization step includes:

- The current optimization step, when applicable.

- Initial LP objective function value (the upper bound on the final solution for the current step), and the number of iterations taken to find this solution.

- The objective function value of each integer MILP solution accepted as the current best solution, and the corresponding branch and bound iterations. This is the current lower bound on the optimal solution.

During the optimization process, the upper bound may be revised to a reduced value. At any point, the MILP algorithm attempts to find an integer solution whose value is the same as the upper bound. Further, only those branches having the potential to produce MILP solutions larger than the current lower bound are analyzed.

Optimization Statistics

This section prints a summary of the optimization process. It includes the value of the best objective function and the number of iterations and re-inversions performed. Note that the objective function is a linear sum of directional bandwidths as a fraction of the cycle length, each band having an associated weight (coefficient).

Solution Report

A solution report is printed for each alternate solution saved by the optimization routine. The number of final reports depends on user selection and the number of solutions actually found. Note that the system reference point for all offsets is the start of the A-direction through green at signal 1 of arterial 1. A solution report includes:

- Network-wide summary giving the optimal cycle length and progression bands for each arterial.

- Summary for each arterial in the network including:
  - Directional bands,
  - Efficiency and attainability,
  - Phase sequences selected,
  - Phase settings as fractions of cycle length,
  - Phase settings in seconds,
  - Travel times and speeds, and
  - Time-Space diagram.
- A signal-by-signal solution section includes:
  - NEMA phases and their durations, and
  - Measures of effectiveness for each approach. These include: approach delays, delay-based level of service, volume-to-capacity (v/c) ratios, and v/c-based level of service.

The total CPU time is printed at the end of the output report. This time is dependent on the type of microprocessor, cache memory and disk drive installed in the computer.

PROLOGUE

This marks the beginning of the Reference Section of the PASSER IV User's Manual. This section is intended for both new and experienced users. As a user becomes more and more experienced with the program, however, this section will tend to become more useful. As opposed to the Getting Started Section, this Section provides full details about the program capabilities and is organized alphabetically to promote quick access to needed information.

PASSER IV Main Screen

When PASSER IV is first selected, you will see the main screen. Figure 5 shows the main screen. The main screen has several components that are described in the following:

- The top line displays the program name, its version, and a user selected organization name.

- The second line from the top is the Main-Menu bar. All Main-Menu selections are provided on this line.

- The bottom line is the **Status Line**. This line is divided into two sections. The left section of this line provides context sensitive information. The right section identifies the currently loaded PASSR4 files. This includes: the *groupname*, and the existing data (*.dat*) and/or output (*.out*) files in the group.

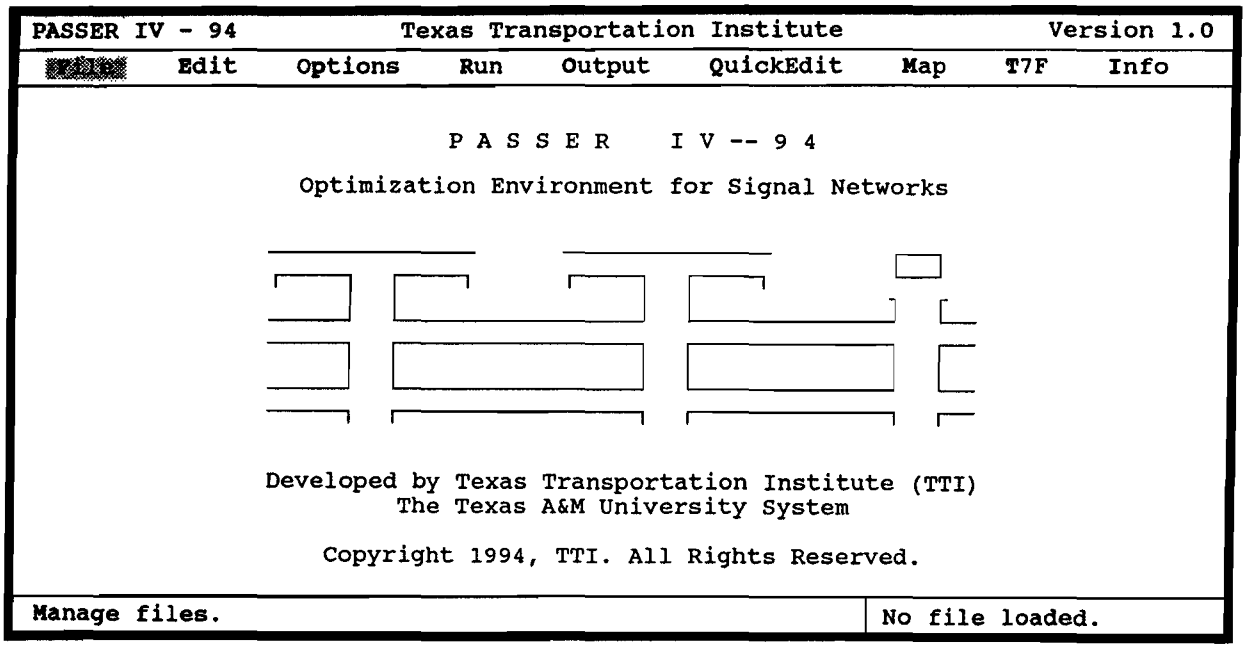
- The middle section of the screen is used to display: sub-menus, input data screens, program output, and network map.

PASSER IV Main-Menu

The operation of PASSER IV is controlled through its Main-Menu. The items on the Main-Menu are arranged logically according to the order in which these options are expected to be used in general. The Main-Menu consists of the following items:

File Edit Options Run Output QuickEdit Map T7F Info

The File, T7F, and Info items provide several functions accessible by using the pull-down sub-menus. The associated pull-down menu appears when any one of these items is selected. The bold letters are the hot-keys. Any menu item can be executed by pressing the associated hot-key. In addition, from any sub-menu, any Main-Menu item can be selected by simultaneously pressing the <Alt> key and the desired hot-key.



PASSER IV - 94 Texas Transportation Institute Version 1.0

PASSER IV -- 94

Optimization Environment for Signal Networks

Developed by Texas Transportation Institute (TTI)
The Texas A&M University System

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Manage files.

No file loaded.

Figure 5: Main screen

Edit

The Edit function allows easy data entry/editing of a loaded data file. This function is automatically executed when the New option is selected from the File menu. If no file group is currently loaded, the Edit option will also let the user specify a *groupname*, which could be an existing name or a new one. In general, however, it is assumed that the data to be modified is in the currently loaded data file named *groupname.dat*.

PASSER IV data are assigned the following hierarchical order: system data level, arterial data level, and signal data level. Figure 6 illustrates the PASSR4 data hierarchy tree and the function keys used to move from one screen or level to another. The Edit function uses a free format in the sense that the user can go to any data entry level (screen) by using a pre-specified sequence of keys described below. As an alternative, the mouse can be used by clicking the left mouse button on one of the color-coded options displayed at the right bottom part of each data entry screen. Once on a data screen, however, the user is required to enter a minimum amount of data called the **skeleton data**.

All input data screens follow a general format. This format includes the following key elements:

1. A border defines the extent of the data entry screen.

2. The top line of the border provides information about the location of the current screen on the hierarchy tree. This includes: artery number and/or name, A-direction on the artery, and signal number, when applicable.

3. The lower-right bottom part identifies the applicable function keys. Each of these color-coded items can be activated using the mouse. Moving the mouse cursor to an item and clicking the left button activates that item.

When the Edit function is invoked, the program goes to the System Data screen. The Edit function can be exited only from this screen by pressing the <Esc> key. One exception is when the user chooses to **Q**uit the program using the sequence of keys <Alt> <X>. The following is a general description of the function keys that let the user move between various data entry screens:

<F2>	From Artery screen	To System screen
	From Signal Screen	To Artery screen
	From Phasing screen	To Signal screen

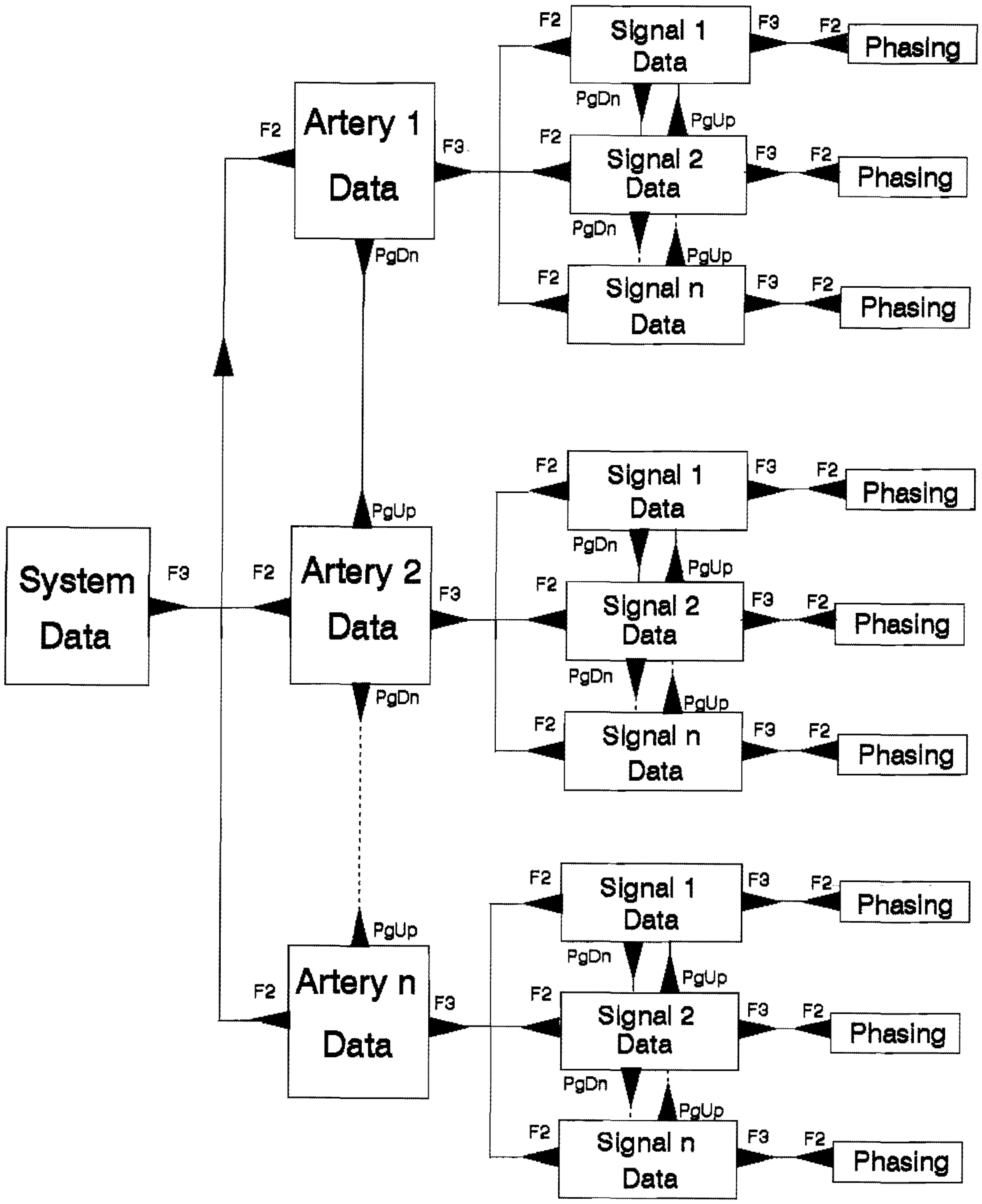


Figure 6: PASSER IV data hierarchy

<F3>	From System screen	To Artery screen
	From Artery screen	To Signal screen
	From Signal Screen	To Phasing screen
<PgUp>	At Artery level	Switches to the previous Artery screen
	At Signal level	Switches to the previous Signal screen
<PgDn>	At Artery level	Switches to the next Artery screen
	At Signal level	Switches to the next Signal screen
<Esc>	From System level	Exits to the Main-Menu.
	From other levels	Same as the <F2> key.

Example: The following sequence of keys will move from the System Data screen to data screen for the 2nd signal on the 3rd arterial.

<F3> <PgDn> <PgDn> <F3> <PgDn>

On any screen, the mouse can be used to go to any data entry field by moving the mouse cursor to that field and pressing the left button. The alphanumeric keys on the keyboard are used for entering data. Other useful keys and their functions are described below.

<Tab>	Moves cursor to the next data field.
<Shift> <Tab>	Moves cursor to the previous data field.
<↑>	Moves cursor to a field on the previous line.
<↓>	Moves cursor to a field on the next line.
<→>	Moves cursor right within the data field.
<←>	Moves cursor left within the data field.
<Backspace>	Deletes data to the left of cursor.
<Delete>	Deletes the data at the cursor.
<Insert>	Toggles insert or overwrite mode.

<Home>	Moves to the first column of the current field.
<End>	Moves to the end of entered data in a field.

The following is a detailed description of data entered on each screen:

System Data Screen

This screen is used to enter systemwide data. Figure 7 illustrates this screen. The middle part of top border identifies the screen. A detailed description of each data entry field is given below followed by notes that provide important details:

Mandatory Data

This data is required by the program. Some of this data is referred to as the skeleton data which is used to define the network structure. The skeleton data on this screen must be entered before exiting the screen. Other data can be entered any time. The following is a listing of these data.

Number of Arteries (skeleton data)
Number of Intersections (skeleton data)
Lower Cycle Length
Upper Cycle Length
Measurement Units
Systemwide Lost Time
Print Input Data Summary
Optimize Signal Timings

Notes:

1. A system can have from 1 to 20 arterials, and from 2 to 35 signalized intersections.

2. Lower limit on cycle length must be less than or equal to the upper limit on cycle length. Same values mean that the cycle length is fixed. In general, signal timing optimization problems having a fixed cycle length will require shorter optimization (CPU) times.

3. Systemwide lost time range is three to five seconds. It is used in green split calculations. Unless a different value is entered on a specific signal screen, this value is used for all signals. In addition, this value is used in the T7F data file.

Artery Data Screen

This screen is used to enter artery-wide data for each arterial. Figure 8 illustrates this screen. The label at the middle of the top border identifies this screen. The right part of the top border gives the number of the current artery. The status line at the bottom provides context sensitive information about each data field and the name of the file group. A description of data items is given below, followed by notes on the use of these data items:

Mandatory Data

These data include skeleton data that must be entered on this screen for each artery in the network. The skeleton data is used to identify network geometry and linkages.

Number of signals (skeleton data)
A-direction (skeleton data)
Time scale
Distance scale
Artery priority
Directional priorities
Average speeds for each direction
Speed range for each direction
Maximum allowed speed change between links

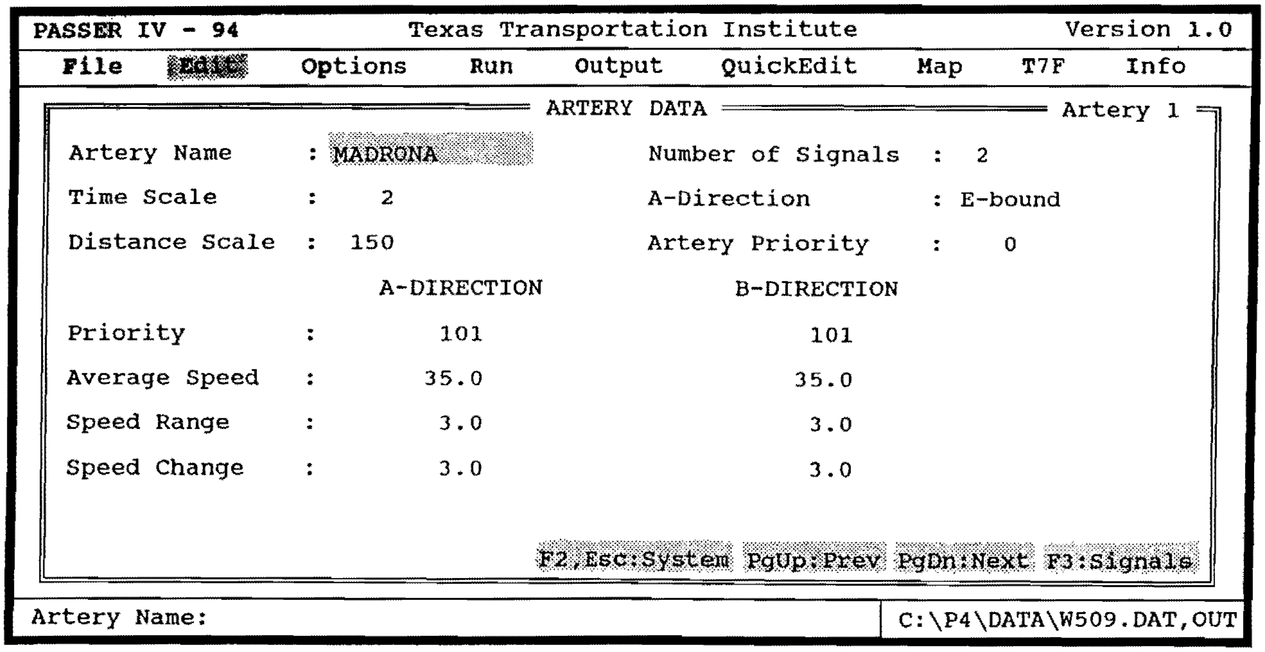
Notes:

1. Number of signals on an artery may be from 2 to 20.

2. The A-direction can be N (northbound), S (southbound), E (eastbound), or W (westbound). The A-direction definition is mainly required to distinguish and identify data for the two directions entered on Signal screens.

3. Time Scale units are the number of seconds per character. This is used for generating a time-space diagram. If the field is left blank, a value of 3 is assumed by default. In any case, if the given or assumed value is not sufficient to show full progression bands, this number is changed by the program later.

4. Distance scale units are feet per line or meters per line depending on whether English or Metric units are selected. The default values are 67 and 20 for English and Metric units, respectively. This number is used for generating a time-space diagram. Use of a reasonable value, that provides at least 5 lines for the shortest link on the arterial while keeping the complete time-space diagram as small as possible, is suggested.



```
ARTERY DATA                                              Artery 1
Artery Name      : MADRONA            Number of Signals  :  2
Time Scale       :    2               A-Direction        : E-bound
Distance Scale   :  150               Artery Priority    :     0
                      A-DIRECTION          B-DIRECTION
Priority         :        101                  101
Average Speed    :       35.0                 35.0
Speed Range      :        3.0                  3.0
Speed Change     :        3.0                  3.0

Artery Name:                                   C:\P4\DATA\W509.DAT,OUT
```

Figure 8: Artery data screen

5. Artery priority determines the relative importance of one arterial in relation to all other arterials in the network. The range of this field is from 0 to 101, as described below:

0	No priority.
1-100	Specified priority is used.
101	Priority is calculated using total volumes on the arterial.

6. For an arterial, directional priorities specify importance of one flow direction over the other. In addition, these are used to specify a one-way arterial. The following includes more detailed information:

A-Direction	B-Direction	Action/Interpretation by the Program
Blank	Blank	Both values assumed to equal 1.
1	0	One-way arterial in A-direction.
0	1	One-way arterial in B-direction. Only acceptable for single arterial problems.
101	101	Priorities are calculated by the program using the sum of approach volumes for each direction.

If only one field is blank, it defaults to the value given in the other field. Thus, the closed direction on a one-way artery must be assigned a priority of 0 (zero).

7. Average directional Speed, Range, and Change values must be supplied for at least one direction. If one field is blank, the corresponding value from the other field is copied into that field. These values are then used for all links on that arterial. Values for specific links can be changed from the Signal data screen. The value given for Range is added and subtracted from the average speed to define the feasible range of speeds. The Change value defines the variation in optimal speed permitted between two consecutive links. This provides protection against big differences in speeds, from one link to the next, that may not be practically possible. If both Range fields, or both Change fields are left blank, the program sets both values equal to 10% of the average speed entered. Thus, the user must enter 0 (zero) when no variation is to be allowed. Further discussion about these data is provided in the Appendix.

Optional Data

Artery Name is optional and is used in the output report for information purposes.

Signal Data Screen and Associated Pop-Up Window

The signal specific data is entered on the Signal Data screen and the associated phase sequence selection window. A pop-up window for phase sequence selection is accessible from the Signal Screen. Figures 9 and 10 show the signal screen and the pop-up window.

The top border of the Signal Data screen identifies the current artery that the current signal screen is accessed from, the signal number, and the A-direction on the current arterial. In addition, an intersection drawing is provided to identify various movements and approaches. A data field for an approach link is identified by a short arrow, and a movement data field is identified using a long arrow. The placement of an arrow on the intersection drawing shows the direction associated with an approach or movement data field. Other information associated with the intersection drawing includes: names of the two crossing streets, the A-direction for this artery indicated by placing a pair of two arrowheads on the exit link, and the node identification number. As with other data screens described earlier, the skeleton data must be entered on the Signal Data screen. Other data can be entered at any time. The following is a description of data on the Signal Screen.

Mandatory Data

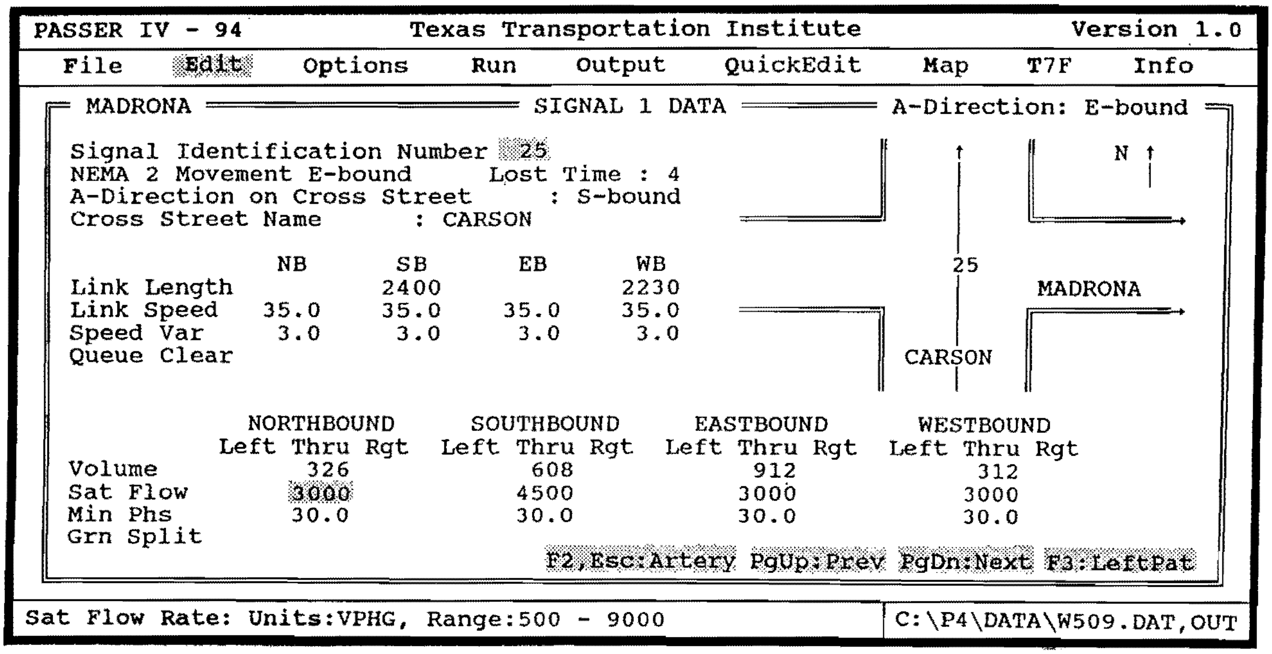
Node Identification Number (skeleton data)
Direction of NEMA 2 Movement
A-Direction on cross street
Link Length
Volumes
Saturation Flow Rates

Optional Data

Lost Time at this signal
Cross Street Name
Link Speed
Speed Variation
Queue Clearance Times
Minimum Phase Times
Green Splits (with exception explained in notes)

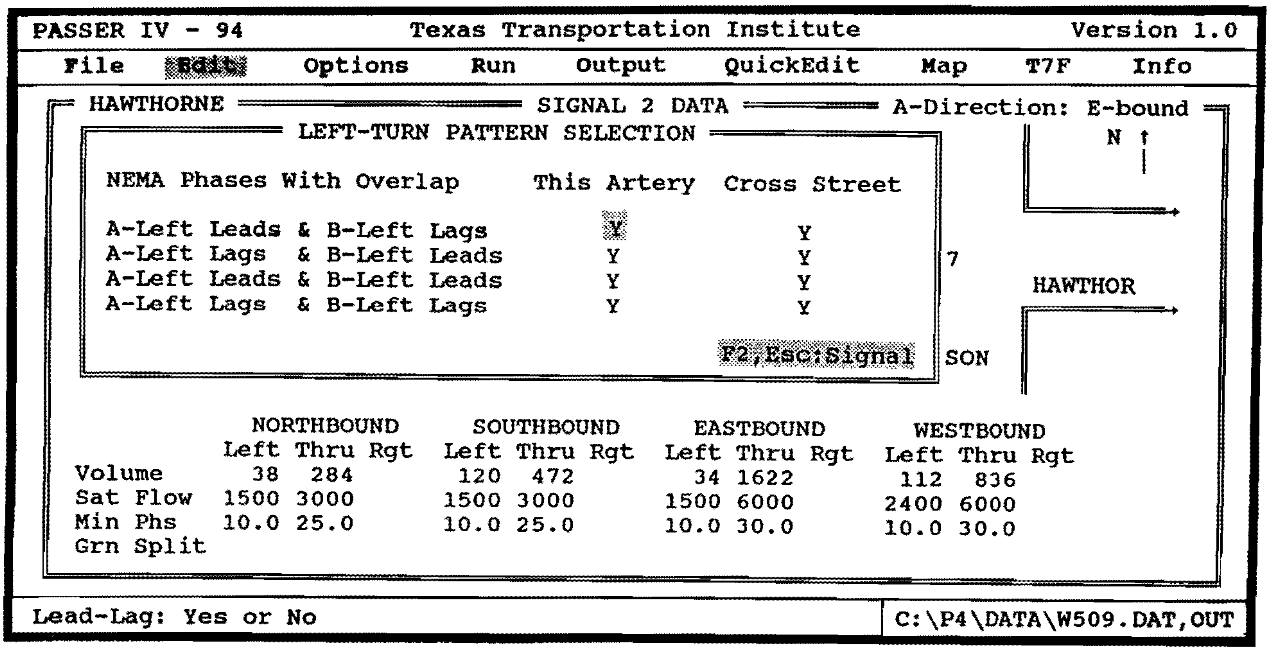
Notes:

1. Lost time, link speed, and speed variation (or range) are given if they are different from the systemwide values.



```
PASSER IV - 94            Texas Transportation Institute            Version 1.0
  File    Edit    Options    Run    Output    QuickEdit    Map    T7F    Info

 MADRONA ============== SIGNAL 1 DATA ======= A-Direction: E-bound

  Signal Identification Number 25
  NEMA 2 Movement E-bound      Lost Time : 4
  A-Direction on Cross Street    : S-bound
  Cross Street Name      : CARSON

                 NB      SB       EB      WB
  Link Length           2400             2230
  Link Speed    35.0    35.0     35.0    35.0
  Speed Var      3.0     3.0      3.0     3.0
  Queue Clear

                NORTHBOUND     SOUTHBOUND     EASTBOUND      WESTBOUND
              Left Thru Rgt  Left Thru Rgt  Left Thru Rgt  Left Thru Rgt
  Volume           326            608            912            312
  Sat Flow         3000           4500           3000           3000
  Min Phs          30.0           30.0           30.0           30.0
  Grn Split
                          F2,Esc:Artery PgUp:Prev PgDn:Next F3:LeftPat

 Sat Flow Rate: Units:VPHG, Range:500 - 9000     C:\P4\DATA\W509.DAT,OUT
```

Figure 9: Signal data screen



```
PASSER IV - 94            Texas Transportation Institute            Version 1.0
  File    Edit    Options    Run    Output    QuickEdit    Map    T7F    Info

 HAWTHORNE ============ SIGNAL 2 DATA ======= A-Direction: E-bound
   ========= LEFT-TURN PATTERN SELECTION =========

    NEMA Phases With Overlap       This Artery   Cross Street

    A-Left Leads & B-Left Lags          Y             Y
    A-Left Lags  & B-Left Leads         Y             Y
    A-Left Leads & B-Left Leads         Y             Y
    A-Left Lags  & B-Left Lags          Y             Y

                                            F2,Esc:Signal

                NORTHBOUND     SOUTHBOUND     EASTBOUND      WESTBOUND
              Left Thru Rgt  Left Thru Rgt  Left Thru Rgt  Left Thru Rgt
  Volume       38  284        120  472        34 1622        112  836
  Sat Flow   1500 3000       1500 3000      1500 6000       2400 6000
  Min Phs    10.0 25.0       10.0 25.0      10.0 30.0       10.0 30.0
  Grn Split

 Lead-Lag: Yes or No                              C:\P4\DATA\W509.DAT,OUT
```

Figure 10: Pop-up window for phase sequence selection

2. Queue clearance times, minimum phase times, and green splits can be supplied in seconds or in equivalent fractions of a cycle. When data entered in one of these fields is greater than 1, it is assumed to be in seconds. In this case, it is automatically converted to fractions of a cycle using the lower cycle length limit supplied by the user.

3. Link length must be entered for all progressed approach links. The number entered is assumed to be in feet or meters, depending on the unit system selected.

4. For each signal, a unique (up to 3 digit) node identification number must be entered. This is used to define the geometry of the network. The choice of signal identification number for a signal, however, is arbitrary.

5. NEMA 2 movement direction must be entered. This is used to print signal timing tables. The NEMA 2 movement direction for each signal may be different. However, since TRANSYT-7F requires this definition to be the same for all signals in the network, the definition selected for the first signal on artery 1 is used in the data file generated for T7F.

6. Either green splits, or volume and saturation flow (Satflow) rates must be given. If splits are given, they are used regardless of the volume and satflow rates. Otherwise, volumes, satflow rates, and lost times are used to calculate green splits using Webster's method.

7. If volumes are not supplied, measures of effectiveness are not calculated.

8. Saturation flow rates for main through lanes for an open direction must be entered. If the saturation flow rate for a left or right turn movement is zero or not supplied, it is assumed that any corresponding traffic movement shares the through lane. In this case, the movement volumes are added to through lane volumes by the program.

9. A-direction for the cross street is only required for a minor cross street and is used to assign NEMA numbers for printing the signal timing tables. If this field is left blank, the program assumes this direction to be the direction of movement at the signal approach next to the arterial A-direction, using clockwise rotation. As an example, if A-direction on the current artery is northbound, westbound will be assumed for this field. However, in order to minimize any confusion, the user should enter a value.

The pop-up window allows the selection of possible phasing sequences for the current signal. The user may choose all or a sub-set of the applicable options. The labels on the window are self-explanatory. A phasing sequence option is chosen by entering a 'Y' in front of a specific option. An 'N' must be typed for all non-applicable options. The following is a list of options for the current artery and cross-artery/street.

i. A-direction left-turn leads and B-direction left-turn lags
ii. A-direction left-turn lags and B-direction left-turn leads
iii. A-direction left-turn leads and B-direction left-turn leads
iv. A-direction left-turn lags and B-direction left-turn lags

The program selects the option, from the user chosen set, that maximizes progression bandwidth for both directions of the artery.

Notes:

1. The user can select the full set (Y for all four options) when the progressed arterial has protected left-turn phases on both approaches.

2. When only one arterial approach has a protected left-turn phase, only two options may be selected.

3. When there are no protected left-turn phases, the user should not choose any option (i.e., an N must be typed for all options)

4. For minor cross streets, exactly one option from the possible set must be chosen, since the program does not optimize signal timings for those arteries/streets. This information is only used to generate the signal timing tables.

File Sub-menu

PASSER IV works with a group of user files. The naming convention for these files is the same as that of DOS. However, the user can only select a file name (called *groupname*) without the DOS extension. The *groupname* is comprised of up to 8 characters. The extension including the period (.) is appended by the program as appropriate. The extensions used by PASSER IV are as follows:

.dat Input data file for PASSR4. This file is created when the user enters data for a problem and saves it to the data file. This data file is needed by the optimization routine, PASSR4. The data file can be created using the UI or using an independent text editor.

.out Output file created by PASSR4. This file may contain only input data summary, only best signal timings, or both. At the user's request and only when multiple solutions exist, PASSR4 can print signal timings corresponding to the multiple alternate signal timings. However, all solutions are contained in the same output file. In addition, from the **O**ptions item of the Main-Menu, the user may request a print of the optimization performance plot (OPP). The OPP consists of information about the status of the search procedure whenever an event occurs. If chosen, this information is also displayed on the monitor.

*.ti** At the option of the user, PASSR4 can generate one or more input data files for use with the TRANSYT-7F (T7F) program. One file is generated for each alternate signal timing solution reported in the file *groupname.out* (i.e. *groupname.til* for the first solution, *groupname.ti2* for the second solution, etc.). A T7F input data file is formed using the user supplied data and a specific set of signal timings including the corresponding bandwidth constraints. This file can be used for bandwidth-constrained delay minimization using T7F.

*.to** This file is generated by T7F when it is run from the UI. The **R**un option from within the T7F sub-menu lets the user select one of the existing input data files and generates a corresponding T7F output file. For example, using an input data file named *groupname.ti2* will result in an output file named *groupname.to2*. The user must have the T7F program on their computer in order to use the **T**7F menu.

The PASSER IV File menu provides various file management functions. Figure 11 shows this sub-menu. Items on this sub-menu are described in the following:

Open <F4>

Loads an existing file group. The group may contain one or more of the following files:

PASSER IV Data file (*groupname.dat*)
PASSER IV Output file (*groupname.out*)
TRANSYT Data file(s) (*groupname.ti**)
TRANSYT Output file(s) (*groupname.to**)

When this option is selected, the program displays a window showing the existing PASSR4 data (*.dat*) and output (*.out*) files. See Figure 12 for an illustration. When all files cannot be shown at a time, the user can use the <PgDn>, <PgUp>,< ↓ >,or < ↑ >keys to view other files. The mouse can also be used to scroll the list of file names by using the scroll bar provided at the right edge of this window. In addition, pressing a letter from the keyboard will take you to the first file name starting with that letter. The list of T7F files can be viewed from the **T**7F menu by selecting any one of the available options.

Save <F5>

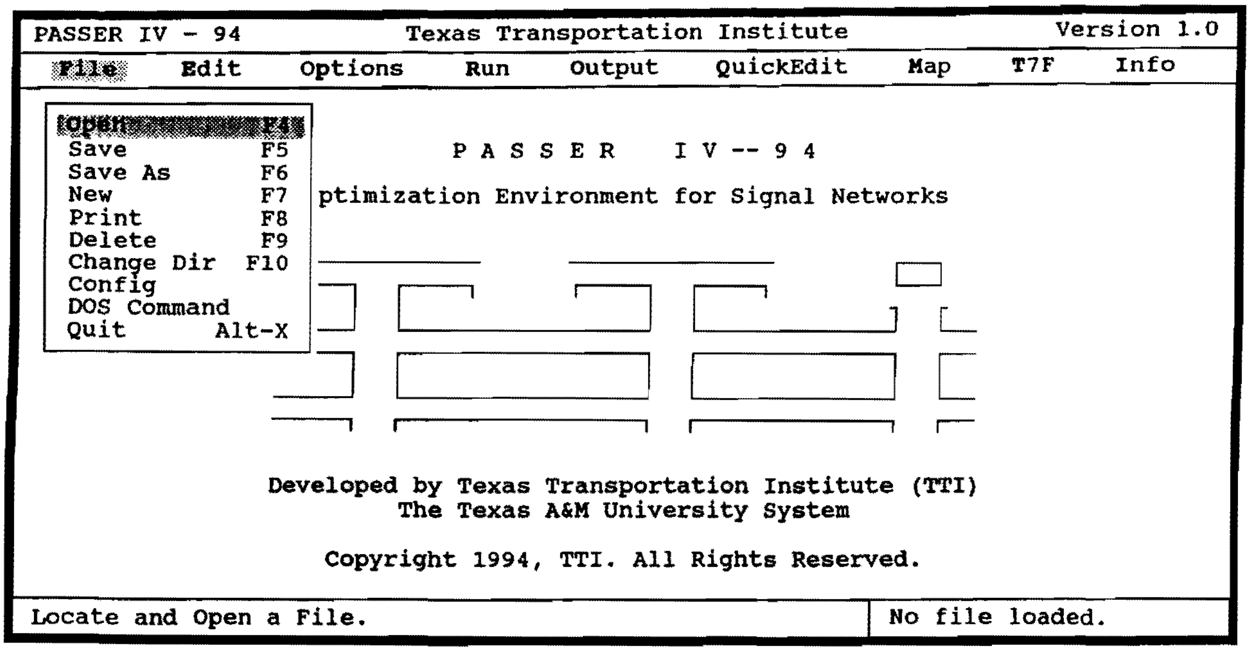
Saves the currently loaded/edited PASSR4 data file (*groupname.dat*).

SaveAs <F6>

Saves the current data file (*groupname.dat*) with a different user-specified name, for example, *newname.dat*. It also changes the current (loaded) group name to the *newname*.

New <F7>

Lets the user select a new, previously unused, *groupname*. After a new *groupname* has been entered, the program automatically executes the Edit function of the Main-Menu, allowing the user to create the PASSR4 data (*.dat*) file corresponding to the new *groupname*.



P A S S E R   I V -- 9 4

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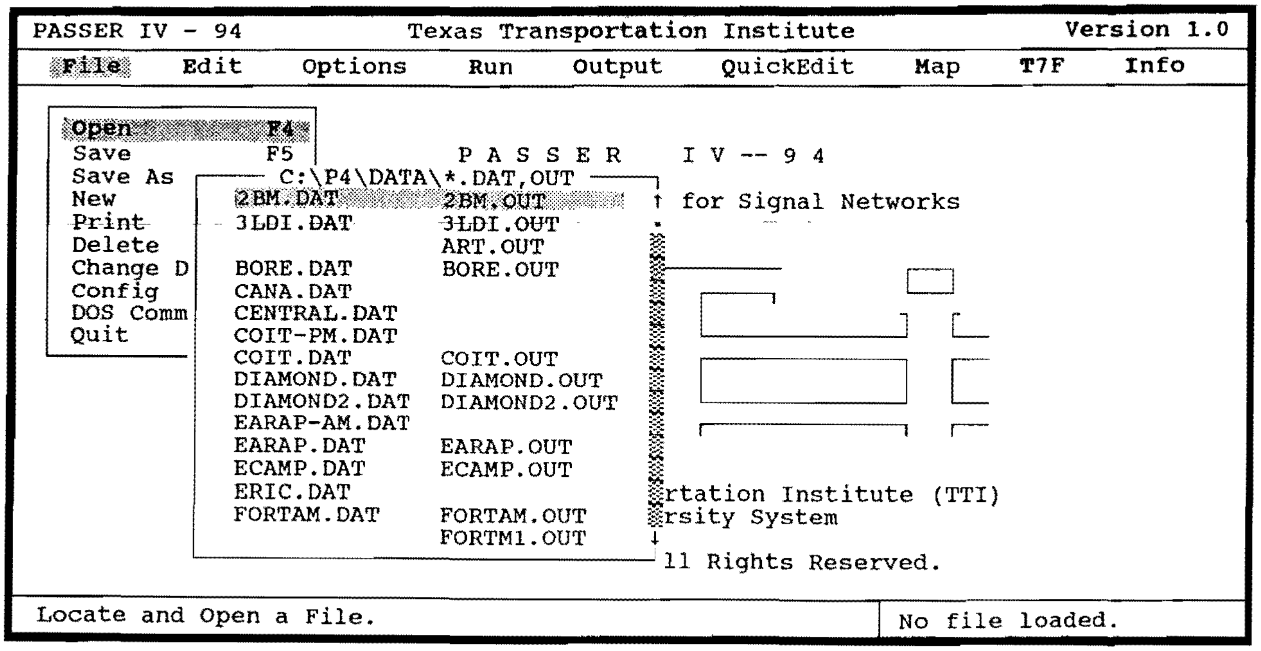
Locate and Open a File.

No file loaded.

Figure 11: File sub-menu



P A S S E R   I V -- 9 4

```
C:\P4\DATA\*.DAT,OUT
2BM.DAT         2BM.OUT
3LDI.DAT        3LDI.OUT
                ART.OUT
BORE.DAT        BORE.OUT
CANA.DAT
CENTRAL.DAT
COIT-PM.DAT
COIT.DAT        COIT.OUT
DIAMOND.DAT     DIAMOND.OUT
DIAMOND2.DAT    DIAMOND2.OUT
EARAP-AM.DAT
EARAP.DAT       EARAP.OUT
ECAMP.DAT       ECAMP.OUT
ERIC.DAT
FORTAM.DAT      FORTAM.OUT
                FORTM1.OUT
```

for Signal Networks

rtation Institute (TTI)
rsity System

11 Rights Reserved.

Locate and Open a File.

No file loaded.

Figure 12: Window showing a sub-set of existing files

Print <F8>

Prints a specified file. This is a generic print function that can be used to print ASCI files such as PASSER IV user files.

Delete <F9>

Deletes a PASSER IV data (*filename.dat*) or output file (*filename.out*) from the current (default) data directory. The capability to delete TRANSYT files in the currently loaded group is given under the T7F option of the Main-Menu.

Change Directory <F10>

Lets the user change the current (default) data directory name. Note, that the program will initially set the data path to that given in the configuration file. This option provides a capability for using files stored in directories or drives other than that specified in the configuration file without having to change the system configuration.

Config

Used to change system configurations and to store them on the configuration file named *p4config.sys*. The system configuration file contains values that are used when the PASSER IV program is executed. These include:

1. Organization name (optional). Default is "Texas Transportation Institute."
2. Default path for user files. Default is ..\data.
3. Location of TRANSYT-7F program. If blank, it is assumed that TRANSYT is not available.
4. Three sets of tolerance values, any one of which can be selected from the Options screen of the Main-Menu by using the <F1>key. These are used by MPCODE, the optimization module of PASSR4.

Dos Command

For executing any DOS command without exiting the program.

Quit <Alt><X>

Exit PASSER IV. At any time and from anywhere in the program, the user can quit PASSER IV by simultaneously pressing the two key sequence <Alt><X>. When this sequence of keys is used, the program gives the user an option to save the last modifications to the data file *groupname.dat*.

Pressing the highlighted letters, or use of arrow keys followed by the <Enter> key will invoke the desired sub-menu item. The function keys (for example, <F4> for opening or loading a group of files in the specified *groupname*), when applicable, allow the user to invoke corresponding file functions from either the **File** menu or the Main-Menu.

Info Sub-menu

Provides general information about the PASSER IV program. Figure 13 illustrates this sub-menu. First time users are strongly encouraged to read this information. This Main-Menu option has the following sub-menu:

Rights

Displays the copyright information and outlines the user responsibilities.

PASSER IV **F**iles

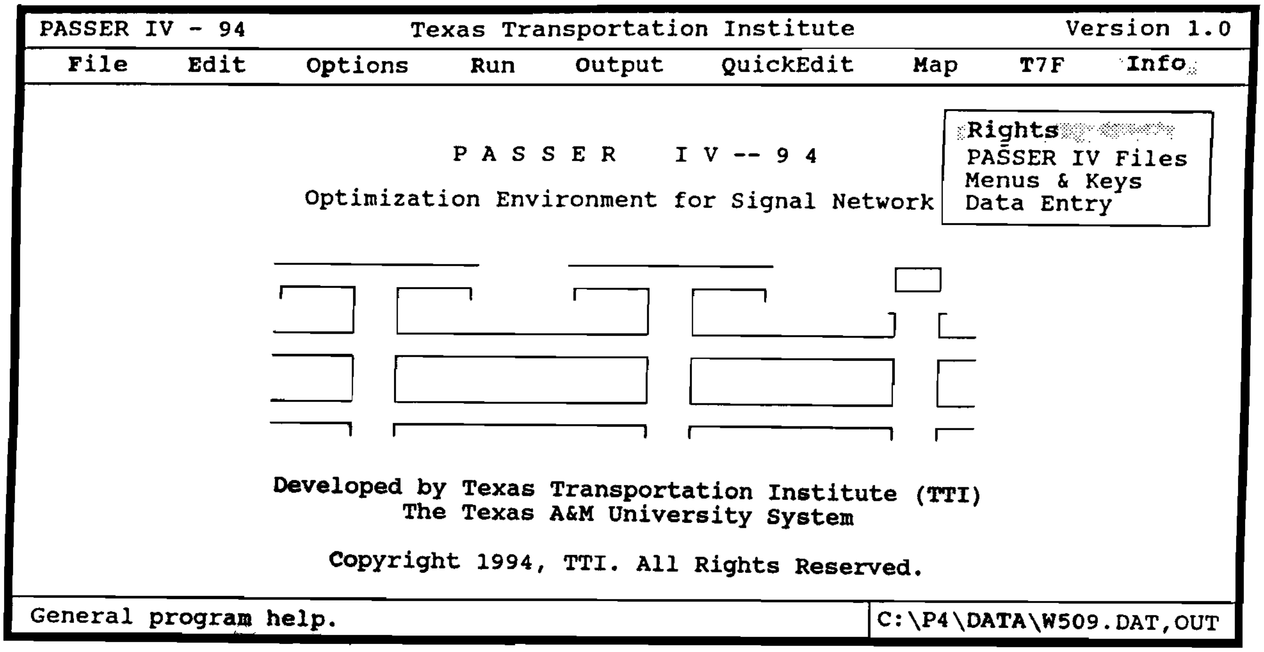
Gives the names and descriptions of PASSER IV files.

Menus & **K**eys

Provides general information about the various keys and their function.

Data Entry

Describes the general data entry scheme.



PASSER IV - 94 Texas Transportation Institute Version 1.0

PASSER IV -- 94

Optimization Environment for Signal Network

Developed by Texas Transportation Institute (TTI)
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General program help. C:\P4\DATA\W509.DAT,OUT

Figure 13: Info sub-menu

Map

This Main-Menu option lets the user view the map of the network defined in the currently loaded data file *groupname.dat*. Figure 14 illustrates the map of a 5-arterial 9-intersection network. All skeleton data must be present in order to display a map which uses node numbers to identify signals. All two-way arteries are drawn using solid blocks, while one-way arteries are drawn using directional blocks showing the one-way flow direction. Arteries are identified by the sequence numbers assigned to them in the order arterial data are entered. The A-direction of an artery is indicated by placing the artery identifier (i.e.,A1, A2, A3.) immediately after the last signal in that direction. For example, the A-direction for the second arterial, the signals for which were entered in order (6-7-8-9-10), is westbound. Thus, A2 was placed to the west of signal 10. Similarly, A3 is placed to the south of intersection 27 to show that the A-direction for the third arterial is southbound. In addition, the middle top border of the screen displays either the network name or the word SYSTEM when no name has been provided. Please note that the map drawing capability of PASSER IV uses characters and is able to draw horizontal and vertical lines only. Thus, arteries forming a triangular network, a rare case, are displayed separately.

The map of a network can be used to visually and directly edit user data. This is accomplished by selecting an entity from the screen using arrow keys or using the mouse. To select an entity, either press <Enter> or click the left mouse button at the desired entity. The map screen has the following entities:

1. System: Network name or the word SYSTEM; at the middle of the top border.

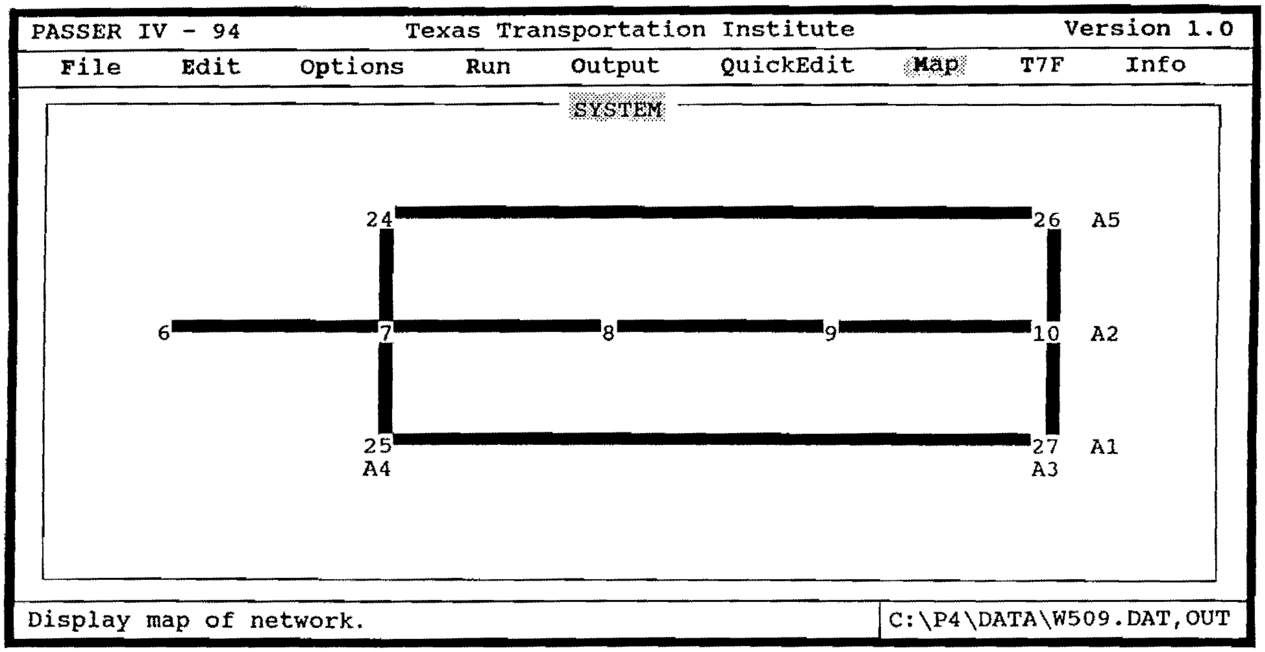
2. Artery sequence number (identifier) displayed after the last signal in the A-direction.

3. Signal identification number.

When an entity is selected, the system moves directly to the data entry screen for that entity. Once on a specific data screen, data can be entered or modified as explained in the Edit section. If a signal is selected, the artery with the smallest sequence number at that signal is referred to as the current artery. Pressing the <Esc> key or the right button on the mouse brings you back to the Map screen. This capability can be used to create data files extremely efficiently by following these two steps:

1. Use the Edit option from the Main-Menu to enter the skeleton data. Make the necessary changes to the network structure (for example, adding or deleting arteries and signals) using the QuickEdit option.

2. Then select the Map option to enter the traffic data.



Display map of network.

C:\P4\DATA\W509.DAT,OUT

Figure 14: Map screen showing the graph of a sample network

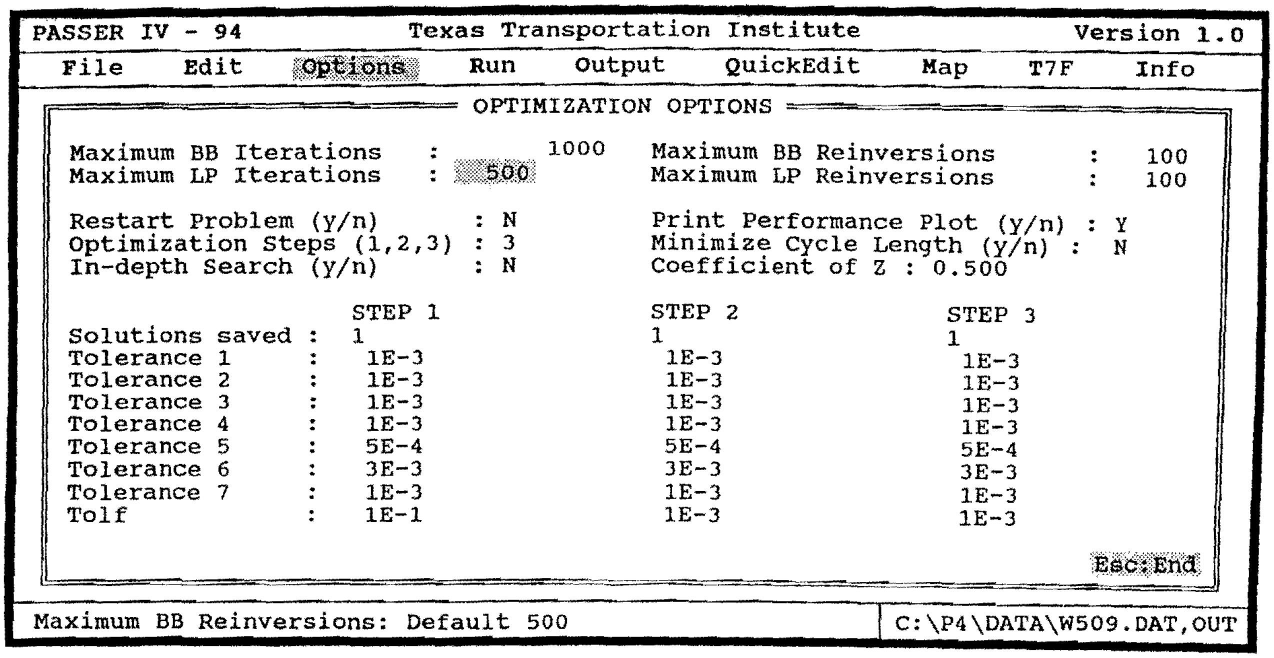
Options

This screen, illustrated in Figure 15, lets the user specify the data used to control MPCODE, the mathematical optimization module of PASSR4. PASSR4 formulates a given signal synchronization problem as a mixed-integer linear program (MILP). MPCODE optimizes this MILP using the branch and bound (BB) algorithm. The data specified on the Options screen is used by the BB algorithm and is placed on a separate screen in order to distinguish it from the traffic data. This section only presents a brief description of the optimization data and related concepts. For a more detailed discussion of these concepts, please refer to the Getting Started Section (page 9) of this manual.

A BB algorithm begins by solving a linear program (LP). The optimal LP solution (objective function value) defines the target total bandwidth. If this LP solution satisfies all integer (synchronization and phasing sequence selection) constraints, the BB algorithm is done. If not, the BB algorithm starts creating a decision tree by adding integrality constraints. At each branch an LP is solved. When a feasible signal timing solution is found at a branch, that solution replaces the current best solution. The algorithm then creates and searches other branches for a better integer solution. When the current best integer solution reaches the target value, the BB algorithm stops and control is passed to the OUTPUT routine to generate signal timings. A user may request the program to save a specified number of best signal timing solutions.

Each step of calculations by the LP algorithm is called an iteration. The CPU time required for an iteration is dependent upon the size of the problem (i.e., the number of variables and constraints). Thus, an iteration for a single arterial problem will require a lot less time than that for a multi-arterial network problem. For a specific problem, the number of iterations required by an LP algorithm is predictable. In rare events, an LP algorithm may fail to converge due to a cycling problem. For such cases, MPCODE allows the user to specify a maximum number of iterations that is used as an upper limit. The BB algorithm will be terminated if a specific LP sub-problem reaches this limit. In addition, MPCODE also keeps a record of the total number of iterations, called BB iterations, from the start to the end. When this number reaches the user-specified limit, the algorithm terminates and a report is generated based on the best solution found thus far. Maximum BB iterations are specified by the user in order to tell the algorithm to stop when the specified limit has been reached.

At the end of an LP iteration, certain columns of the problem matrix must contain values of either 0 or 1. Due to round-off errors, however, these columns may contain other values (i.e., 0.0000001, or 0.99999). MPCODE is equipped with a data correction feature called re-inversion. Whenever such data errors are encountered, MPCODE performs a re-inversion which places 0's and 1's in the appropriate places. Too many re-inversions



```
                    OPTIMIZATION OPTIONS

Maximum BB Iterations   :        1000  Maximum BB Reinversions     :  100
Maximum LP Iterations   :   500        Maximum LP Reinversions     :  100

Restart Problem (y/n)         : N      Print Performance Plot (y/n) : Y
Optimization Steps (1,2,3)    : 3      Minimize Cycle Length (y/n)  :  N
In-depth Search (y/n)         : N      Coefficient of Z : 0.500

                    STEP 1             STEP 2              STEP 3
Solutions saved :   1                  1                   1
Tolerance 1     :    1E-3               1E-3                1E-3
Tolerance 2     :    1E-3               1E-3                1E-3
Tolerance 3     :    1E-3               1E-3                1E-3
Tolerance 4     :    1E-3               1E-3                1E-3
Tolerance 5     :    5E-4               5E-4                5E-4
Tolerance 6     :    3E-3               3E-3                3E-3
Tolerance 7     :    1E-3               1E-3                1E-3
Tolf            :    1E-1               1E-3                1E-3

Maximum BB Reinversions: Default 500          C:\P4\DATA\W509.DAT,OUT
```

Figure 15: Optimization data screen

beyond a certain limit, however, is indicative of computational problems with the data and should not be allowed. Two numbers, the maximum number of re-inversions for a specific LP sub-problem, and the maximum number of BB iterations are specified by the user to protect against these problems. When any one of the user-specified numbers is reached, the BB algorithm terminates and prints the best solution found.

A tolerance is a number that is used to detect data errors and to compare whether two numbers are equal. MPCODE uses a set of eight tolerance values for comparing key variables. A default set of tolerances is used in PASSER IV. Normally, the user will have no need to change these values. In addition, three sets of tolerance values are pre-specified in the PASSER IV configuration file. When the cursor is at any tolerance field, the user can press the <F1> key to retrieve any of these sets. See the notes given below for guidelines. The last of these tolerances, TOLF, is used to compare the current best solution value to the next best solution candidate. The next best solution is only accepted when it is TOLFx100 percent better than the current best solution. If judiciously used, TOLF can help speed up the search process by not considering those tree branches that do not have the potential to provide the specified amount of improvement.

The optimization data include:

Maximum BB Iterations
Maximum BB Re-inversions
Maximum LP Iterations
Maximum LP Re-inversions
Restart Problem (y/n)
Print Performance Plot (y/n)
Optimization Steps (1,2,3)
Minimize cycle length (y/n)
Coefficient of Z
In-depth Search (y/n)
Solutions Saved
Tolerances
Tolf

Notes:

1. The upper limits on iterations and re-inversions set as default are sufficient for most problems. Maximum BB iterations are the only data that a user is expected to change frequently. When a problem is prematurely terminated, the program creates a restart file containing the status of the optimization process. This provides the user an option to restart the optimization process from the point it terminated. An unfinished problem

can be restarted by setting the restart flag to yes, increasing the critical iteration or re-inversion limit, and re-running the problem. The program then reads the optimization status from the restart file and continues the optimization process. Note that the restart option can only be used to restart the first optimization step of a problem.

2. If a reasonable set of limits on iterations and re-inversions is unable to generate a feasible solution, the tolerances should be increased. It is suggested that the current tolerance set be only increased by 10 percent. Reducing the tolerance values is suggested when the search procedure does not reach a good feasible solution. When the cursor is at a tolerance data field, the user can select one of the pre-specified set of tolerances by using the <F1> key.

3. Optimization steps specify whether the global (1-step) or either heuristic (2 or 3-step) optimization method is to be used. In general, the highest applicable number is recommended. The following are some additional guidelines:

Network type and valid optimization procedures	
Single arterials and open networks with no left-turn phases	1 Step
Single arterial and open networks with left-turn phases	1 and 2 Step
Closed loop networks with one-way arterial only	1 Step
Closed loop networks with no left-turn phases	1 and 2 Step
Closed loop network with left-turn phases and two-way arterials	All

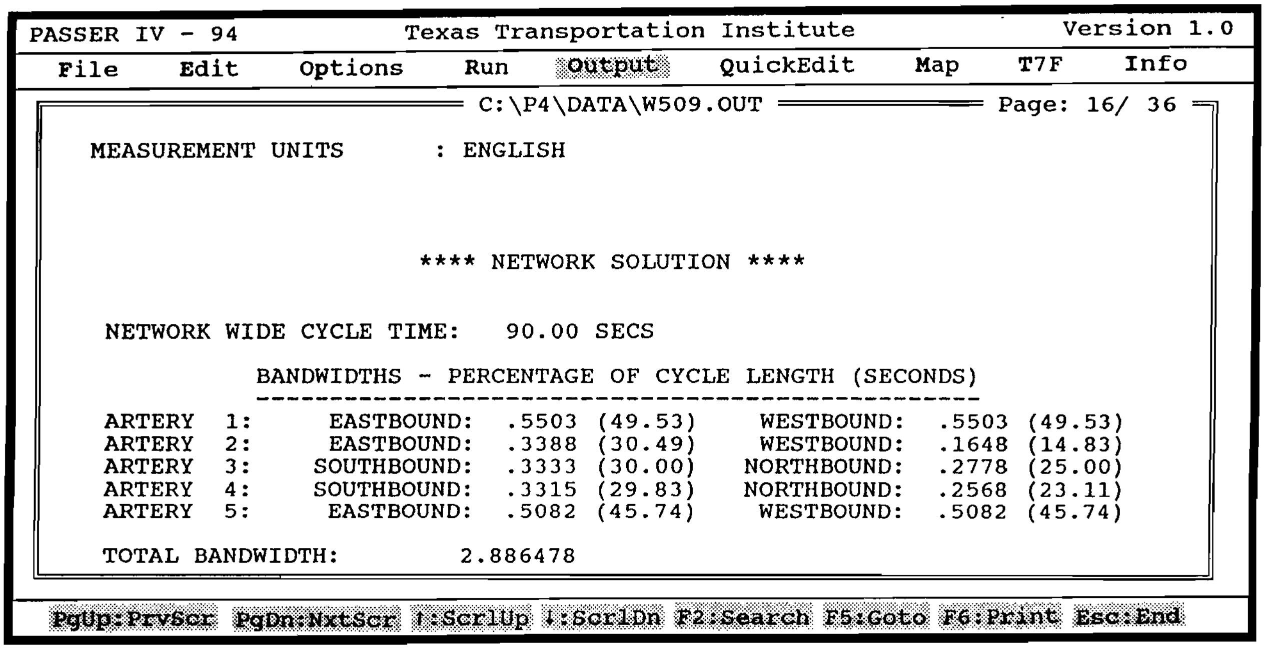
4. A user can specify the maximum solutions to be saved at each optimization step. When a heuristic optimization method is selected, the chances of obtaining a good solution are increased by requesting the algorithm to save multiple solutions at intermediate steps. The maximum number of solutions requested to be saved at the last step of a selected optimization procedure determines the number of solutions to be reported. Note, however, that requesting multiple solutions will require more CPU time.

5. Many times, multiple solutions with the same bandwidth efficiency will exist. These solutions may have different cycle lengths. Cycle length minimization allows the selection of the solution with the lowest cycle length in the specified analysis range. The coefficient of Z (inverse of cycle length) is the weight given to cycle length minimization in the objective function. The larger the coefficient, the higher the priority given to the maximization of Z (minimization of cycle length). For a balanced objective function, a value should be selected from the interval [0.5,1.0].

Output

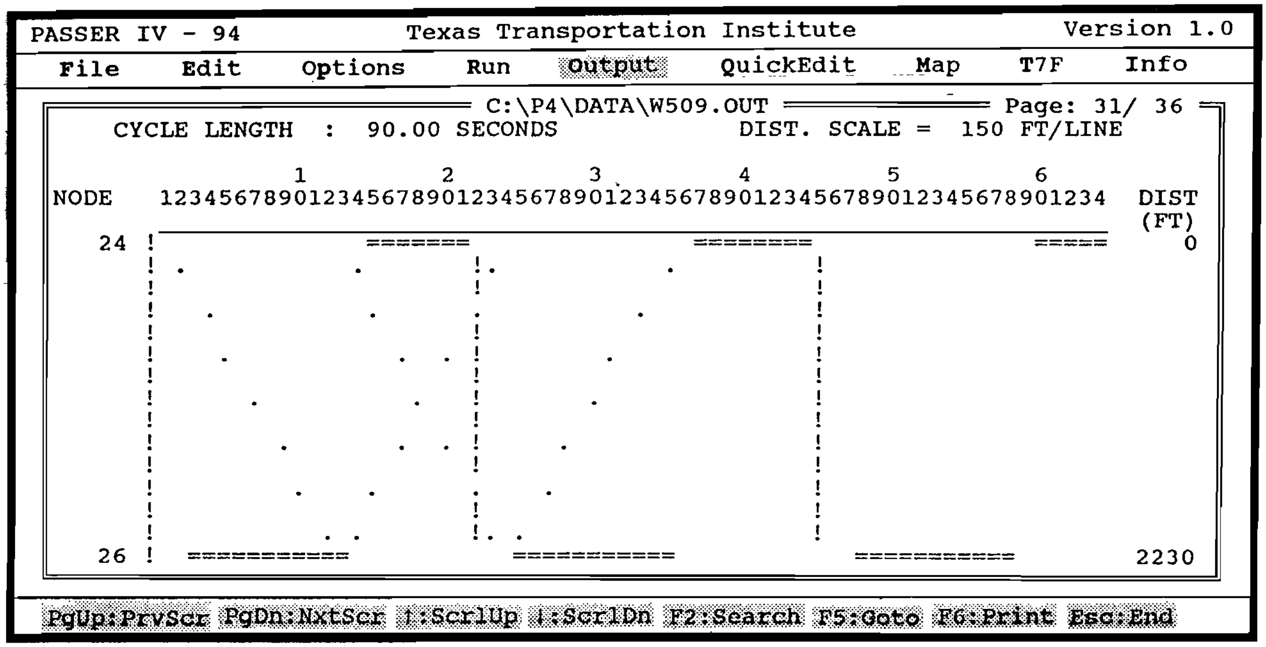
This Main-Menu option lets the user view and/or print the currently loaded PASSER IV output file (*groupname.out*). The output file name is displayed at the center of the top border of the window. The right top corner of the window displays the current page and total number of pages in this file. A page refers to a page of printed output. On the screen, a line is drawn to show page breaks. Figures 16 and 17 show sections of a sample output. The output function has several useful features. These include an ability to go to predefined sections of the output file, a capability to print selected sections, and a string search capability. The following is a description of keys used for moving around in the output file and for printing sections of this file.

<PgUp>	Screen up.
<PgDn>	Screen down.
<Ctrl> <PgUp>	Top of previous page.
<Ctrl> <PgDn>	Top of next page.
<Home>	Beginning of the file.
<End>	End of the file.
<↑>	Scroll one line up.
<↓>	Scroll one line down.
<F2>	Search menu and definition of search string.
<F3>	Search forward for selected string.
<F4>	Search backward for selected string.
<Enter>	Accept selected item.
<Esc>	Cancel command.
<F5>	Invokes the go-to sub-menu. Sub-menu items are described as follows:
<I>	Go to the Input Card section of output.
<D>	Go to the Input Data Summary section of output.
<O>	Go to the Optimization Performance Plot section.
<P>	Go to the Signal Timing Solution section.
<A>	Go to the previous artery signal timings section.
<a>	Go to the next artery signal timings section.
<B>	Go to the previous sub-section.
<b>	Go to the next sub-section.
<S>	Go to the previous section.
<s>	Go to the next section.
<R>	Go to the previous alternate solution, if any.
<r>	Go to the next alternate solution, if any.



```
C:\P4\DATA\W509.OUT                 Page: 16/ 36

   MEASUREMENT UNITS      : ENGLISH



                           **** NETWORK SOLUTION ****


    NETWORK WIDE CYCLE TIME:    90.00 SECS

              BANDWIDTHS - PERCENTAGE OF CYCLE LENGTH (SECONDS)
              ------------------------------------------------
    ARTERY  1:     EASTBOUND:  .5503 (49.53)     WESTBOUND:  .5503 (49.53)
    ARTERY  2:     EASTBOUND:  .3388 (30.49)     WESTBOUND:  .1648 (14.83)
    ARTERY  3:    SOUTHBOUND:  .3333 (30.00)    NORTHBOUND:  .2778 (25.00)
    ARTERY  4:    SOUTHBOUND:  .3315 (29.83)    NORTHBOUND:  .2568 (23.11)
    ARTERY  5:     EASTBOUND:  .5082 (45.74)     WESTBOUND:  .5082 (45.74)

    TOTAL BANDWIDTH:         2.886478
```

Figure 16: Output window showing network solution



```
C:\P4\DATA\W509.OUT                 Page: 31/ 36
   CYCLE LENGTH  :  90.00 SECONDS            DIST. SCALE =  150 FT/LINE

                1         2         3         4         5         6
NODE   1234567890123456789012345678901234567890123456789012345678901234  DIST
                                                                         (FT)
  24  !              =======               ========               =====     0
      ! .           .       !.           .         !
      !                     !                      !
      !   .          .      .          .           !
      !                     !                      !
      !    .           .  . !        .             !
      !                     !                      !
      !      .          .   !       .              !
      !                     !                      !
      !        .       .  . !     .                !
      !                     !                      !
      !         .    .      .    .                 !
      !                     !                      !
      !           . .       !. .                   !
  26  !  ===========           ===========            ===========        2230
```

Figure 17: Output window showing a time-space diagram

<F6>	Print Menu.
<P>	Print this page.
<B>	Print this sub-section.
<S>	Print this section.
<F>	Print whole output file.

Please refer to the Getting Started section for information about the contents of output file (*groupname.out*).

QuickEdit

As described in the Getting Started Section, PASSR4 reads the data file (*groupname.dat*) created by the user. Whereas the **Edit** feature allows the viewing of data in a fully-labeled form and then writes it to this file, the **QuickEdit** feature lets you directly edit this data file. When this item is selected, it invokes a built-in text editor and loads the data file for editing. Figure 18 illustrates the text editor window. The text editor provides the following functions:

- Delete characters: The <Backspace> key deletes a character to the left of the cursor, and the <Delete> key deletes the character at the cursor.

- Delete current line: Simultaneously pressing the <Ctrl> and <Y> keys.

- String search capability: The <F2> key is used to define the string to be searched, and <F3> (<F4>) searches the next (previous) occurrence of the defined string.

- Block operations: The <F5> key defines the beginning of the block at the current cursor position. <F6> defines the end of block to be at the current cursor position. The selected block is displayed in reverse video mode. <F7> copies the selected block starting at the current cursor position. <F8> moves the defined block to the current cursor position. A block of text can also be defined using the mouse as follows:

  1. Move mouse cursor to the beginning of block and press the left mouse button,

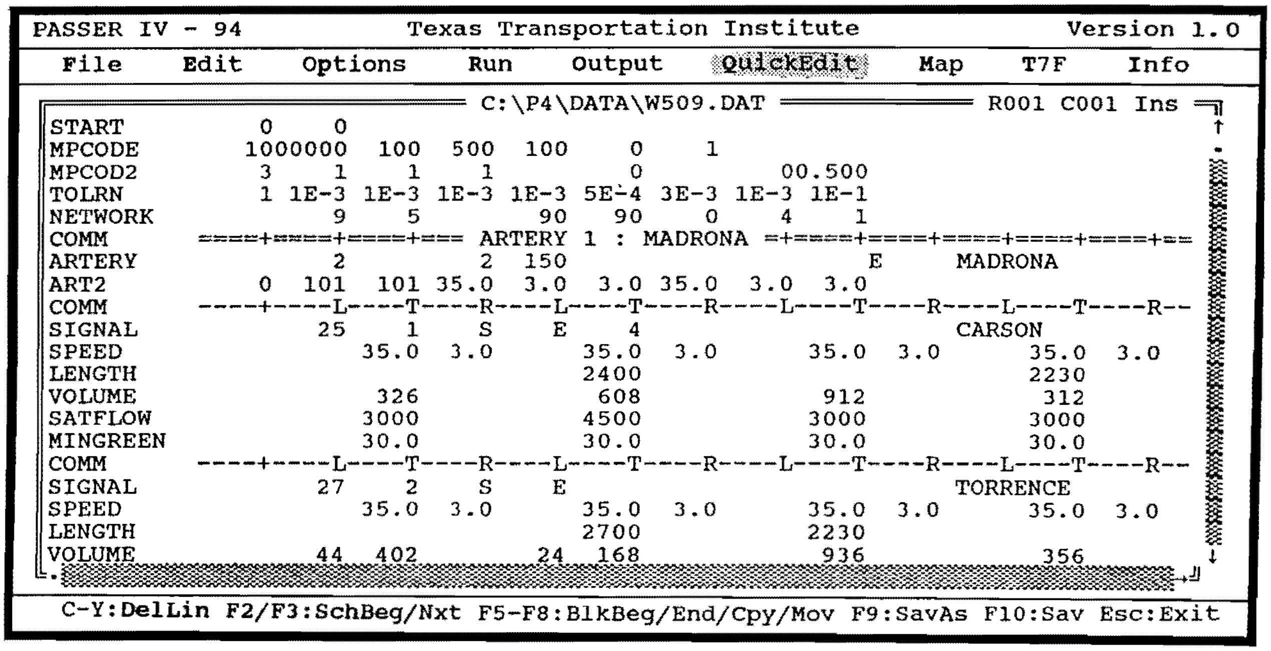
  2. Keeping the mouse button pressed, move the mouse to define the block, and

  3. Release the mouse button.

- Saving the file: Pressing <F9> saves the changes to the currently loaded file. Pressing <F10> saves the files with a new name specified by the user.

- Exiting **QuickEdit**: Pressing <Esc> exits the text editor. It also checks for data errors and, when necessary, gives an option to save modifications to the current file.

Experienced users can use this capability to perform quick modifications to the data. In addition, with a minimum understanding of the structure of the data file, a user can easily add and delete arterials and intersections. This capability combined with the **Map** option in the Main-Menu can be used to efficiently create and edit data files. The basic structure of the data file is given in Figure 19. Description of data records used to create the data file follows:



```
C:\P4\DATA\W509.DAT                                R001 C001 Ins
START         0    0
MPCODE       1000000  100  500  100    0    1
MPCOD2        3    1    1    1         0         00.500
TOLRN         1 1E-3 1E-3 1E-3 1E-3 5E-4 3E-3 1E-3 1E-1
NETWORK            9    5        90   90    0    4    1
COMM      ====+====+====+=== ARTERY 1 : MADRONA =+====+====+====+====+==
ARTERY             2         2  150                    E     MADRONA
ART2          0  101  101 35.0  3.0  3.0 35.0  3.0  3.0
COMM      ----+----L----T----R----L----T----R----L----T----R----L----T----R--
SIGNAL            25    1    S    E    4                     CARSON
SPEED                35.0  3.0      35.0  3.0      35.0  3.0      35.0  3.0
LENGTH                              2400                          2230
VOLUME                326            608            912            312
SATFLOW              3000           4500           3000           3000
MINGREEN             30.0           30.0           30.0           30.0
COMM      ----+----L----T----R----L----T----R----L----T----R----L----T----R--
SIGNAL            27    2    S    E                          TORRENCE
SPEED                35.0  3.0      35.0  3.0      35.0  3.0      35.0  3.0
LENGTH                              2700           2230
VOLUME            44  402        24  168            936            356

C-Y:DelLin F2/F3:SchBeg/Nxt F5-F8:BlkBeg/End/Cpy/Mov F9:SavAs F10:Sav Esc:Exit
```

Figure 18: Text editor screen

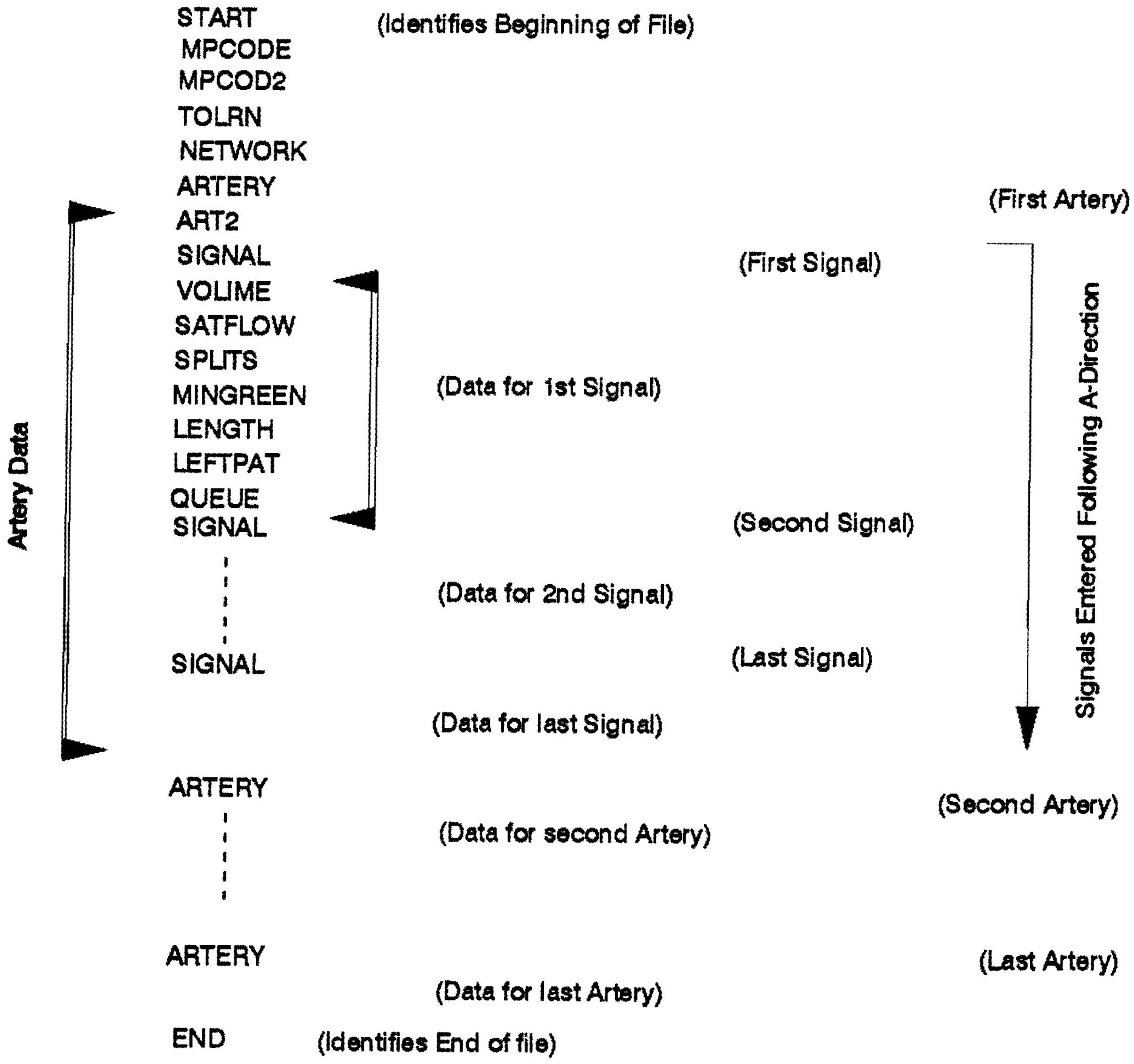


Figure 19: Structure of PASSR4 input data file

Data are entered on input data records (also called cards) with unique names. The data cards are identified by their names. Each card name must be typed, using capital letters, starting in the first (left most) column of a line. ~~Some cards are used only once,~~ while other cards are used as needed to fully define the network and traffic data. For detailed information about data fields, please refer to the section that describes the Edit option. The following is a description of each card type:

START Card (Refer to: Edit/System Data Screen section)

This card is used only once at the beginning of the data file, and is used to select the output and warning level. If this card is missing, a warning message is printed and the maximum output level is assumed. Detailed description of information on this card follows:

Warning Level

Column 10	0	Print warning messages.
	1	Do not print warning messages.

Output Level

Column 15	0	Check data, optimize signal timings, and print full report.
	1	Same as 0, but only print solution report.
	2	Check data only, print summary report, do not optimize.
	Blank	Same as 0.

Run Number
Columns 16-20 (optional data)

District Number
Columns 21-25 (optional data)

Date
Columns 35-40, Format; mm/dd/yy (optional)

City Name
Columns 62-77 (optional)

MPCODE Card (Refer to: Options section)

This card is optional and is used to provide the following data for the MPCODE optimization module:

Maximum Branch and Bound Iterations
Columns 11-20

Maximum Branch and Bound Re-inversions
Columns 21-25

Maximum Linear Program Iterations
Columns 26-30

Maximum Linear Program Re-inversions
Columns 31-35

Restart This Problem

Column 40	0	Not a restart problem.
	1	Restart this problem using user data and the restart file. The file restart.out should be renamed to restart.dat. If PASSR4 is being run from the UI, the restart file is automatically renamed.

Print MPCODE Performance Plot

Column 45	0	Do not print performance plot.
	1	Print performance plot.

MPCOD2 Card (Refer to: Options section)

This optional card is used to select the following data for the MPCODE optimization program.

Optimization Procedure

Column 15	1	Simultaneous optimization of all variables.
	2	Two-Step optimization.
	3	Three-step optimization.

Solutions Saved In Step-1
Column 20, Range 1 to 5.

Solutions Saved In Step-2
Column 25, Range 1 to 5. Only valid for 2-Step and 3-Step methods.

Solutions Saved In Step-3
Column 30, Range 1 to 5. Only valid for 3-Step method.

In-depth Search

Column 40	0	No.
	1	Yes.

Minimize cycle length

Column 50	0	No.
	1	Yes.

Objective Function Coefficient of Z (1/C, the inverse of cycle length)
Columns 51-55; Range 0 to 10.

TOLRN Card (Refer to: Options section)

This card is used to supply tolerances for the MPCODE optimization module. A TOLRN card can be supplied for each step. If no TOLRN card is given, default values of tolerances are used.

Optimization Step
Column 15, number identifies the optimization step for which this information applies.

Tolerances 1 to 7, and TOLF
Column 16-20; Default value 1.0x10^{-3}.
Column 21-25; Default value 1.0x10^{-3}.
Column 26-30; Default value 1.0x10^{-3}.
Column 31-35; Default value 1.0x10^{-3}.
Column 36-40; Default value 5.0x10^{-4}.
Column 41-45; Default value 3.0x10^{-3}.
Column 46-50; Default value 1.0x10^{-3}.
Column 51-55; Default value 0.

Note: Format of these fields is xxEy (i.e., 1.5E5 = 0.000015).

NETWORK Card (Refer to: Edit/System Data Screen section)

This card is mandatory and is used to supply thc following information:

Number of signals in the network
Columns 19-20. Valid range is 2 to 35.

Number of arteries in the network
Columns 24-25. Valid range is 1 to 20.

Lower cycle length
Columns 33-35. Valid range is 40 to 200 seconds.

Upper cycle Length
Columns 37-40. Valid range is 40 to 200, and larger than the lower limit.

Measurement units
Column 45 0 English (i.e., distance in feet and speed in miles per hour).
1 Metric (i.e., distance in meters and speed in kilometers/hour).

Systemwide lost time
Column 50. Range 3, 4, or 5 seconds.

Network name
Columns 62-77 (optional)

ARTERY Card (Refer to: Edit/Artery Data Screen section)

This card is mandatory and identifies the beginning of data for an arterial. A SETUP card must be given to identify each arterial in the network. The following information is given on this card:

Number of signals on this artery
Column 19-20. Range 2 to 20.

Time scale for time-space diagram
Column 26-30. Default 3 seconds/character.

Distance scale for time-space diagram
Column 31-35. Default 67 feet/line or 20 meters/line.

A-direction for this arterial
Column 56; Rangc N, S, E, or W (i.e. Northbound, Southbound, etc.)

Artery name
Columns 62-77 (optional)

ART2 Card (Refer to: Edit/Artery Data Screen section)

This card is mandatory and must follow each SETUP card. The following information is given on this card:

Weight of artery compared to other arteries

Columns 13-15	0	Ignore.
	1-100	Uses specified weight.
	101	Calculated using total volumes on artery.

Weight of A-direction of artery

Columns 18-20	0	For more information refer to Edit section.
	1-100	User specified weight.
	101	Calculated using total directional volumes.

Weight of B-direction of artery

Columns 23-25	0	For more information refer to Edit section.
	1-100	User specified weight.
	101	Calculated using total directional volumes.

Average travel speed in A-direction for the entire artery
Columns 29-30

Speed variation in A-direction (used to define a range of speed for the entire artery)
Columns 34-35

Allowed speed changes between adjacent links in A-direction
Columns 39-40

Average travel speed in B-direction for the entire artery
Columns 44-45

Speed variation in B-direction (used to define a range of speed for the entire artery)
Columns 49-50

Allowed speed changes between adjacent links in B-direction
Columns 54-55

SIGNAL Card (Refer to: Edit/Signal Data Screen section)

The card name must be given in columns 1-6. This card is mandatory for each traffic signal on an arterial. The SIGNAL card marks the beginning of data for a signal. The following information is provided on this card:

The node identification number
Columns 18-20

Signal sequence number
Columns 24-25. Sequential order of the signal along the A-direction. The UI automatically assigns this number; but, it must be entered here when the data file is created or modified using the text editor.

A-direction for cross street
Column 30. Range N, S, E, or W.

Direction of NEMA 2 movement flow
Column 35. Range N, S, E, or W.

Lost time at this signal
Column 40. Range 3 to 5 seconds.

Cross artery/street name
Columns 62-77 (optional)

VOLUME Card (Refer to: Edit/Signal Data Screen)

The units of this turning movement volume data are vehicles per hour, vph.

Northbound: Left volume; Columns 16-20.
Through volume; Columns 21-25.
Right volume; Columns 26-30.

Southbound: Left volume; Columns 31-35.
Through volume; Columns 36-40.
Right volume; Columns 41-45.

Eastbound: Left volume; Columns 46-50.
Through volume; Columns 51-55.
Right volume; Columns 56-60.

Westbound: Left volume; Columns 61-65.
Through volume; Columns 66-70.
Right volume; Columns 71-75.

SATFLOW Card (Refer to: Edit/Signal Data Screen)

The unit of this saturation flow data are vehicles per hour green, vphg.

Northbound: Left saturation flow rate; Columns 16-20.
Through saturation flow rate; Columns 21-25.
Right saturation flow rate; Columns 26-30.

Southbound: Left saturation flow rate; Columns 31-35.
Through saturation flow rate; Columns 36-40.
Right saturation flow rate; Columns 41-45.

Eastbound: Left saturation flow rate; Columns 46-50.
Through saturation flow rate; Columns 51-55.
Right saturation flow rate; Columns 56-60.

Westbound: Left saturation flow rate; Columns 61-65.
Through saturation flow rate; Columns 66-70.
Right saturation flow rate; Columns 71-75.

MINGREEN Card (Refer to: Edit/Signal Data Screen)

This data can be entered as seconds or as fractions of the cycle. If the entered number is larger than 1, it is assumed to be in seconds. In this case, the program automatically converts the number to fractions of the cycle by using the lower cycle length value supplied by the user. These data ensure that minimum green times will be provided.

Northbound: Left minimum green time; Columns 16-20.
Through minimum green time; Columns 21-25.

Southbound: Left minimum green time; Columns 31-35.
Through minimum green time; Columns 36-40.

Eastbound: Left minimum green time; Columns 46-50.
Through minimum green time; Columns 51-55.

Westbound: Left minimum green time; Columns 61-65.
Through minimum green time; Columns 66-70.

SPLITS Card (Refer to: Edit/Signal Data Screen)

The green splits can be entered as seconds or as fractions of the cycle. If the number entered is larger than 1, it is assumed to be in seconds. In this case, the program automatically converts the number to fractions of the cycle by using the lower cycle length supplied by the user. The splits may be modified to satisfy any minimum green times supplied.

Northbound: Left green split; Columns 16-20.
Through green split; Columns 21-25.

Southbound: Left green split; Columns 31-35.
Through green split; Columns 36-40.

Eastbound: Left green split; Columns 46-50.
Through green split; Columns 51-55.

Westbound: Left green split; Columns 61-65.
Through green split; Columns 66-70.

SPEED Card (Refer to: Edit/Signal Data Screen)

The approach speeds are assumed to be in miles per hour or kilometers per hour, depending on the unit system selected by the user. This data overrides artery-wide values.

Northbound: Average Approach Speed; Columns 24-25.
Speed Variation; Columns 29-30.

Southbound: Avcragc Approach Speed; Columns 39-40.
Speed Variation; Columns 44-45.

Eastbound: Average Approach Speed; Columns 54-55.
Speed Variation; Columns 59-60.

Westbound: Average Approach Speed; Columns 69-70.
Speed Variation; Columns 74-75.

LENGTH Card (Refer to: **Edit/Signal** Data Screen)

The approach lengths read from this card are assumed to be in feet or meters, depending on the unit system selected by the user.

Northbound: Approach Link length; Columns 21-25.

Southbound: Approach Link Length; Columns 36-40.

Eastbound: Approach Link Length; Columns 51-55.

Westbound: Approach Link Length; Columns 66-70.

QUEUE Card (Refer to: **Edit/Signal** Data Screen)

The values of queue clearance times given on this card can be in seconds or fractions of a cycle. If a number read is larger than 1, it is assumed to be in seconds. In this case, it is automatically converted to fractions of a cycle using the lower cycle length supplied by the user. When given, the queue clearance times are used to lag the associated arrival time of progression band by this time at the signal.

Northbound: Link Queue Clearance Time; Columns 21-25.

Southbound: Link Queue Clearance Time; Columns 36-40.

Eastbound: Link Queue Clearance Time; Columns 51-55.

Westbound: Link Queue Clearance Time; Columns 66-70.

LEFTPAT Card (Refer to: Edit/Signal Data Screen)

This card is used to select a set of left-turn patterns (signal phase sequences) from which PASSR4 is to choose the best pattern. A value of 1 means that the pattern should be analyzed; a value of 0 means that the pattern is not applicable or should be skipped. Figure 20 illustrates the four possible NEMA phasing sequences.

Main Artery:	Lead-Lag;	Column 15.
	Lag -Lead;	Column 20.
	Lead-Lead;	Column 25.
	Lag -Lag;	Column 30.
Cross Street or Artery:	Lead-Lag;	Column 35.
	Lag-Lead;	Column 40.
	Lead-Lead;	Column 45.
	Lag-Lag;	Column 50.

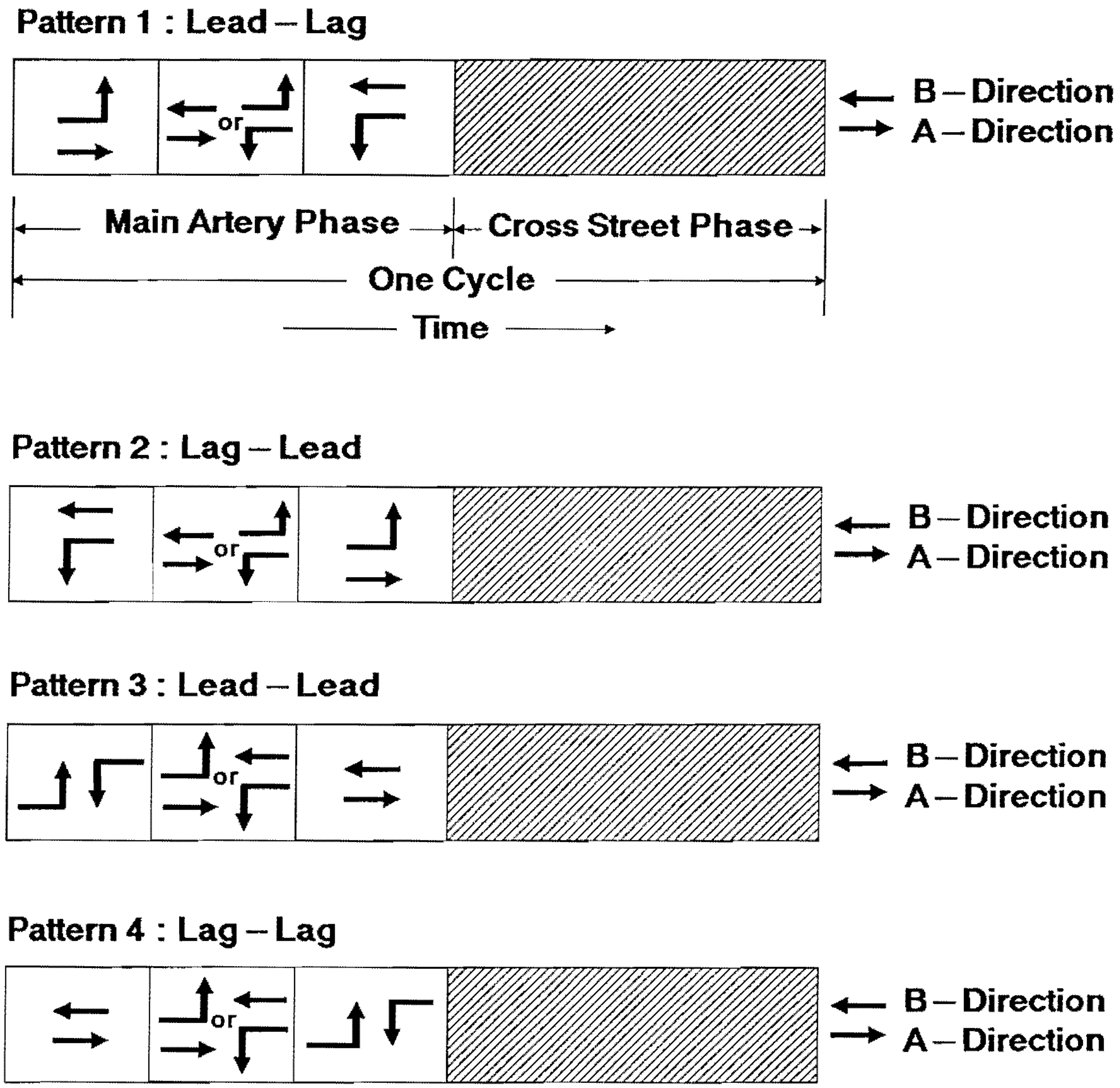
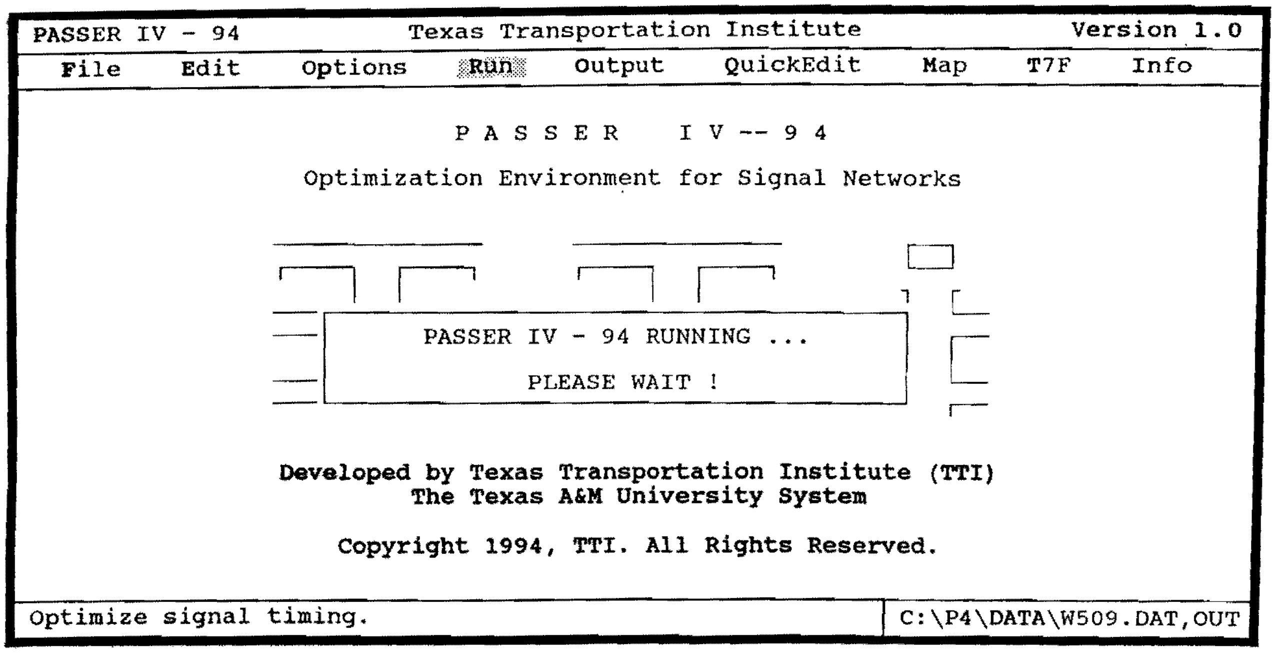


Figure 20: Four possible NEMA phasing sequences

Run

The Run command saves the currently loaded data on the file *groupname.dat* and gives control to the optimization program (PASSR4). Figure 21 illustrates what the main screen looks like when this option is selected. The optimization program then reads this data file, checks the data for errors, performs bandwidth optimization, and creates the file *groupname.out* containing the optimal solution report. At the completion of PASSR4 operation, control is passed back to the UI. The new output file can be viewed or printed from the UI by selecting the **Output** option.

The bandwidth maximization procedure consists of generating a mathematical formulation (a mixed-integer linear program) corresponding to the given data and optimizing this program using a branch-and-bound technique, which in turn optimizes a number of intermediate linear programs. The optimization function is performed by a sub-module called MPCODE. Finally, the solution obtained from MPCODE is used to generate the signal timing report.



P A S S E R   I V -- 9 4

Optimization Environment for Signal Networks

PASSER IV - 94 RUNNING ...

PLEASE WAIT !

Developed by Texas Transportation Institute (TTI)
The Texas A&M University System

Copyright 1994, TTI. All Rights Reserved.

Optimize signal timing.

C:\P4\DATA\W509.DAT,OUT

Figure 21: Action after selecting the Run option

T7F Sub-menu

~~This Main Menu option provides communication links to TRANSYT-7F related~~ functions. This feature is similar to that provided by the Arterial Analysis Package. It provides a capability to facilitate bandwidth-constrained delay minimization of bandwidth solutions generated by PASSR4. In order to use this capability, the user must have the TRANSYT-7F program available. In addition, the correct path of the directory containing T7F must have been specified using the Config option from the File menu. An input data file for T7F contains user supplied input data and bandwidth-based signal timings as the starting solution. This file can be requested using the option given on the System Data Screen. When PASSR4 is requested to save multiple solutions, a T7F file is generated for each solution saved. The T7F sub-menu, illustrated in Figure 22, can be used to run the program using any data file corresponding to the loaded *groupname*. The sub-menu provides the following options:

Edit Data

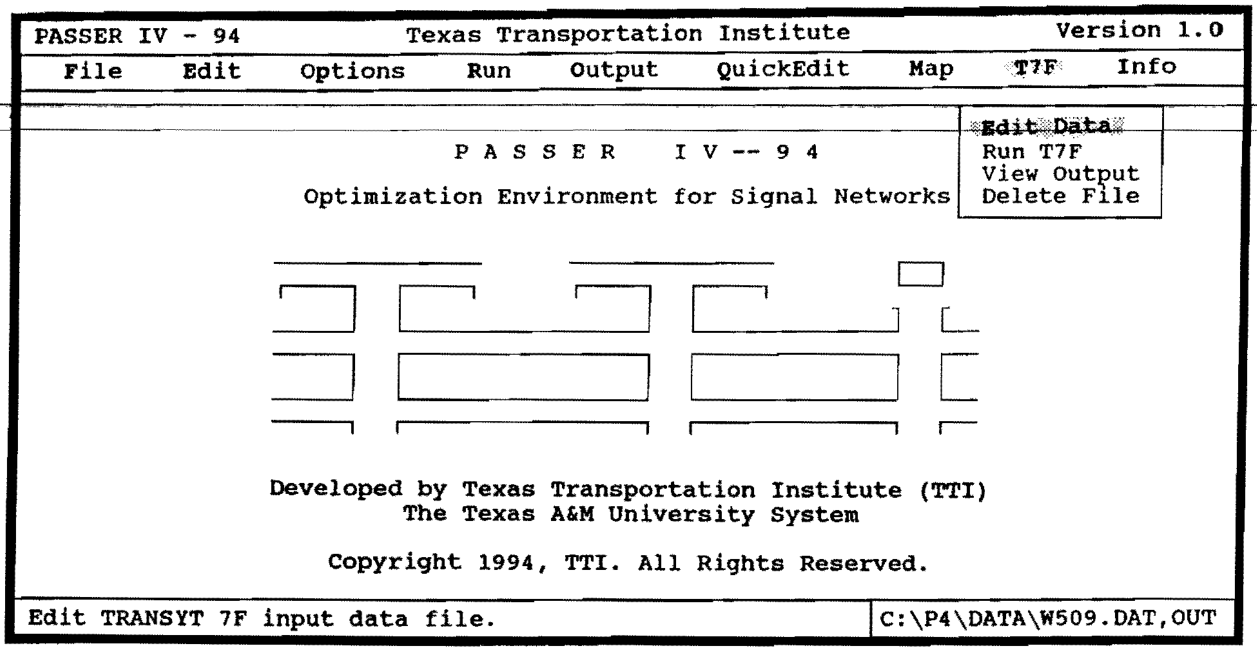
It has the capability to edit any selected data file. The edit facility uses the same built-in text editor as used by QuickEdit. For information on the text editor, please refer to the QuickEdit section. When this option is selected, the program displays the names of all available data files in the current group (see Figure 23). The desired data file can be selected by using arrow keys and then pressing the <Enter> key at the desired file name. As an alternative, the mouse can be used by moving the cursor to the desired file name and clicking the left button. This lets you select a data file for editing. The Edit feature can be used to make modifications to the values of T7F specific data used as default.

Run T7F

Selection of this option lets you run T7F using the specified input data file. When this option is selected, a list of existing data files in the loaded group is displayed. An input data file is selected by using arrow keys and pressing the <Enter> key at the highlighted file name. As an alternative, the mouse can be used by moving the cursor to the desired file name and clicking the left button.

View Output

Selecting this option lets you view the specified output file. An output file from the available list can be selected using arrow keys and by pressing the <Enter> key at the highlighted filename. As an alternative, the mouse can be used by moving the cursor to the desired file and clicking the left button. This option provides the



PASSER IV -- 94

Optimization Environment for Signal Networks

Developed by Texas Transportation Institute (TTI)
The Texas A&M University System

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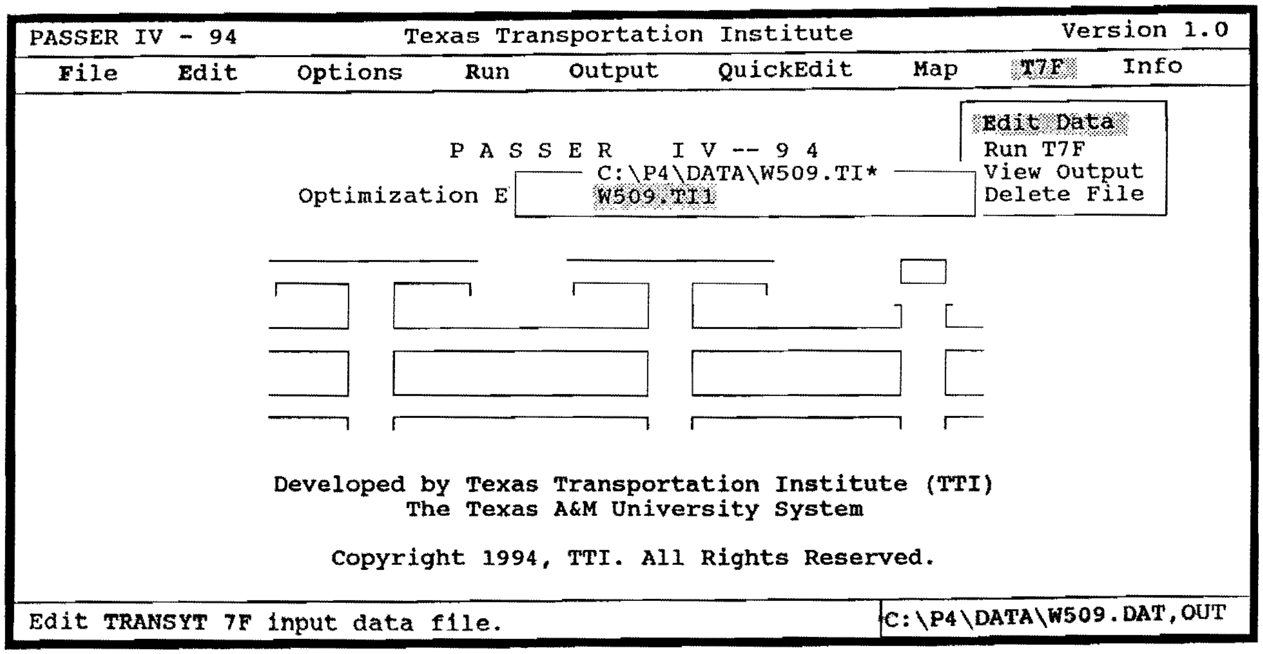
Edit TRANSYT 7F input data file.

C:\P4\DATA\W509.DAT,OUT

Figure 22: T7F sub-menu



PASSER IV -- 94

Optimization E

C:\P4\DATA\W509.TI*
W509.TI1

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The Texas A&M University System

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Edit TRANSYT 7F input data file.

C:\P4\DATA\W509.DAT,OUT

Figure 23: T7F Edit option showing available files to choose from

same capabilities that are provided by the **Output** option of the Main-Menu for viewing PASSR4 output files. Please refer to the **Output** section for detailed information about the usage of keys and functions.

Delete File

Allows you to delete any specified T7F input or output file belonging to the currently loaded *groupname*. When this option is selected, all T7F data and output files in the loaded group are displayed. Any one of these files can be deleted by using arrow keys to select the desired file and pressing the <Enter> key. As an alternative, the mouse can be used by moving the cursor to the desired file name and clicking the left button. Before deleting a file, however, the program gives the user an option to continue the delete operation or to abort without deleting.

Description of Speed Data

~~Desired link speeds and constraints on link speeds are specified using three types of~~ speed data: average link speed, speed range, and allowed speed change between consecutive links. The range of speed for a link, from which the optimal value is to be selected, is defined by average link speed ± speed range. A speed range of zero means that the link speed is fixed at the average link speed coded.

Example 1: If the average link speed and speed range for a link are 30 and 3, respectively, the optimal speed will be selected from the range 27 to 33.

The value entered for allowed speed change controls the maximum difference in the optimal speeds at two consecutive links. This data ensures that the progression speeds on consecutive links are not infeasible to achieve in practice. Thus, in general, allowed speed variation may also restrict the speed defined by the average speed and speed range. The following example illustrates the use of speed change.

Example 2: Suppose that average speed and speed range data for two consecutive A-direction links on an arterial are 30±3 and 35±3, respectively. This means that the allowable speed ranges for the two links are 27 to 33 and 32 to 38, respectively. In the absence of any other constraints, the speed for a link will be selected from its defined range. However, this may lead to speed variation between links that is undesirable. For instance, the program may produce an optimal speed of 27 for the first link and 38 for the next link. In practice, however, it may not be possible for the drivers to achieve this much increase in progression speed from the first link to the next. The constraints on speed variation between links is a means of restricting such large variations. The following cases explain how these constraints are enforced.

1. If the speed change value used is zero (0), it means that the user desires the optimal speeds for the two links to be the same. Thus, the optimal speed for both links will be selected from the range, 32 to 33, defined by the overlap of speed ranges given above for the two links.

2. If the speed change value is 3, the absolute difference between the optimal speeds for the two links will be 3 or less. Thus, the optimal speed for the first link cannot be less than 29 (32-3), while the optimal speed for the second link cannot be more than 36 (33+3).

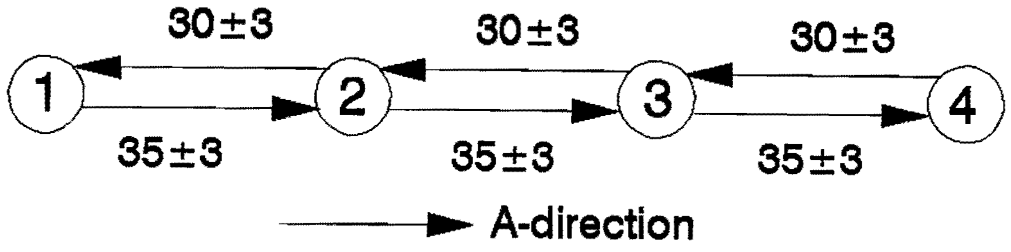
Note that it is possible to supply values of speed data that produce an infeasible search region. The following example illustrates this case:

Example 3: Let the average speed and range data for two consecutive A-direction links be 35±2 and 40±1, respectively. Then, a value of one or less for allowed speed change will create an infeasible region since the minimum speed variation of two (39-37=2) is needed to keep the constraints feasible. If the user supplies such data, the program terminates with an error message.

Entering Speed Data

The program requires that average speed data for at least one direction of an arterial be entered on the Artery Data Screen. If the average speed field for one direction is left blank, the program assumes it to be the same as that given for the other direction. If the speed range and speed change fields for a direction are left blank, these values default to 10% of the average speed for that direction. Thus, a zero must be entered in the appropriate field if either the speed is fixed and/or no speed change between the links is desired. This data (after assuming the default values, when applicable) is then automatically copied to all links on the arterial. The speed change (maximum link-to-link variation) data can only be entered on the Artery Data screen. If a link has different values for average speed and speed range, those values are entered on the Signal Data Screen. The following examples illustrate how to enter speed data:

Example 1: Suppose that the following data is given for a 4 intersection arterial whose A-direction is eastbound:

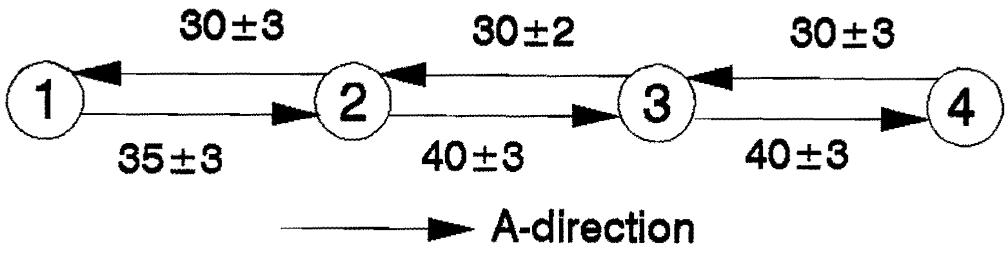


Note that all A-direction links have a speed range of 35±3 and all B-Direction links have a speed range of 30±3. Therefore, this common data will be entered on the Artery Data screen as follows:

	A-Direction	B-Direction
Average Speed	35	30
Speed Range	3	3

This data will be copied to all links.

Example 2: Suppose some speed data given above is modified as shown below:



Note that the first link (from signal 1 to signal 2) in the A-direction has a different speed value (35); whereas, the second link (from signal 3 to signal 2) in the B-Direction has a different speed range value. The program is designed to minimize the amount of data entry. It is suggested that the Artery Data screen be used to enter the data that is the same for the majority of links and the remaining data be entered on the Signal Data screen. Thus, for the current example, entering data in the following manner will be the most efficient method:

1. On the Artery Data screen, enter the following data:

	A-Direction	B-Direction
Average Speed	40	30
Speed Range	3	3

This data will be copied to all links.

2. Go to the Signal Data screen for the second signal on the artery and enter the following data:

	NB	SB	EB	WB
Link speed			35	
Speed Var.				2

This tells the program that the eastbound approach link to signal 2 has an average speed of 35 and the westbound approach link to signal 2 has a speed variation of 2. Thus, the values entered on thc Signal Data screen will override the values entered on the Artery Data screen.

Relationship Between Speed, Offset, and Computation Time

In the PASSER IV formulation, the offset on a link connecting two consecutive signals is treated as a continuous variable. The optimum offset for a link is a function of optimal travel time on that link. Further, optimal average travel time is a function of the speed on that link. Thus, the optimum offset for a link is selected from a range of speeds defined by the user supplied data.

The larger the range of speed on a link, the larger the search region. In general, this will result in more time required to search for the optimal offset. Thus, it is recommended that the ranges of speeds given for all links be as small as possible.

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