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| 16. Abstract <p>PASSER IV is a program for timing traffic signals in networks based on progression bandwidth optimization. This manual describes how to use PASSER IV-96, Version 2.1, 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. Further, 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.</p> | | | |
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PASSER IV-96

Version 2.1

User/Reference Manual

by

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College Station, Texas 77843-3135

IMPLEMENTATION STATEMENT

The enhanced version of the PASSER IV program developed in this project will be helpful to the Texas Department of Transportation traffic engineering professionals who plan, design, operate and maintain signalized interchanges, signalized arterials, and multi-arterial signalized networks. PASSER IV can be used for optimizing the operation of an isolated interchange or for coordinating an interchange with adjacent signals on an arterial. 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 thus reduce delay, fuel consumption, and vehicular emissions. The program's use will also improve the efficiency of the state's traffic engineering professionals in 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.

PASSER IV software and related documentation are copyrighted. The development of the original version of PASSER IV was funded by the Texas Higher Education Coordinating Board (THECB) under their Energy Research in Applications Program and the Texas Department of Transportation (TxDOT), in cooperation with the Federal Highway Administration (FHWA), under their Highway Planning and Research Program. The development of PASSER IV-96, Version 2.1, described in this report, was funded by the Southwest Region University Transportation Center (SWUTC), and TxDOT in cooperation with FHWA under their State Planning and Research Program.

The program is distributed through the 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, SWUTC or McTrans is not liable for any damages (direct or indirect) resulting from the use of this program.

ACKNOWLEDGMENT

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

Several individuals have made significant technical contributions throughout the development of PASSER IV. Ms. Anulark Pinnoi, Mr. Tai-Hsi Wu, Mr. Rajivendra Nath, Mr. Ali Haider Husaini, Ms. Shireen Chada, and Mr. Meher Malakapalli had made significant contributions to the original version of the program. Mr. Bogju Lee developed most of the User Interface and implemented revised data structures in the optimization module. Mr. David Berry programmed several significant enhancements that led to the final version of the User Interface. Mr. Vijay Kovvali, and Ms. Shweta Jain provided help in debugging the software. Mr. Rehan Sheik provided support in the preparation of this report. All of these individuals worked for the Texas Transportation Institute, Texas A&M University, College Station, Texas. We thank all these individuals for their support in the development of PASSER IV.

We would also like to thank Mr. Nader Ayoub, of Texas Department of Transportation (TxDOT) for his continued support. Mr. Ayoub served as the TxDOT Technical Panel chairman for this research project. Special thanks goes to Mr. John Black, City of Richardson, Texas, for his support. Mr. Black provided several real data sets for testing the off-line and the real-time use of the program. He also tested the beta versions of the program.

Finally, we would like to thank those users of the original program (Version 1.2) who have provided us feedback and data sets for debugging the software and those users who tested the beta versions of the software.

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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 millions of dollars to travelers in terms of lost time and excessive fuel consumption and also results in more air pollution. Furthermore, 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, these improvements 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 projects to develop and improve the tools for optimizing signal timings. PASSER IV-96 is the result of the latest project in this area. This report presents the User/Reference manual for PASSER IV-96, Version 2.1.

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, provides many features such as delay estimates, estimates of vehicular emissions and fuel consumption, level-of-service estimates, and is capable of producing alternate best solutions desired by the traffic engineering community. Other features of PASSER IV include the following: capability of processing multiple optimizations as a batch job, option to select the master signal for referencing signal offsets, improved computational efficiency, ability to handle larger networks, improved output report, and options to select different measurement units for input data and output report. These features will enable more efficient use of the software to reduce vehicular emissions and fuel consumption. In a related project, it was estimated that fuel savings in the six largest metropolitan areas in Texas from the use of PASSER IV will be over 6 million barrels by the end of the century. This estimate was based on the assumption that the number of users effectively utilizing the program will increase steadily over a period of several years. This estimate is still applicable, since the number of PASSER IV users have significantly increased in the last year. The improved software will increase the chances of achieving the estimated benefits.

The User/Reference manual is organized to facilitate ease of use for the novice as well as the experienced PASSER IV 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 headings and sub-headings in the reference guide are labeled/classified according to the menus and sub-menus in the User Interface. Various appendices provide information about some unique features of the program. The manual provides an index 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 those 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 arterial 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 arterial in the defined network. The key features of PASSER IV are described as the follows:

1. Allows user-specified or volume-based arterial and directional priorities.
2. Determines the following principal signal timing parameters:
 - Optimal cycle length,
 - Green splits using Webster's method,
 - Signal offsets, and
 - NEMA phasing sequences with and without overlap.
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. Allows a user to specify the master signal and the master direction for use as the offset reference point. In addition, the beginning or ending of the through phase in the master direction can be selected as the offset reference point. Furthermore, a base offset can be specified to offset the beginning of master phase. This feature can be used for time-based coordination of networks in multiple jurisdictions.

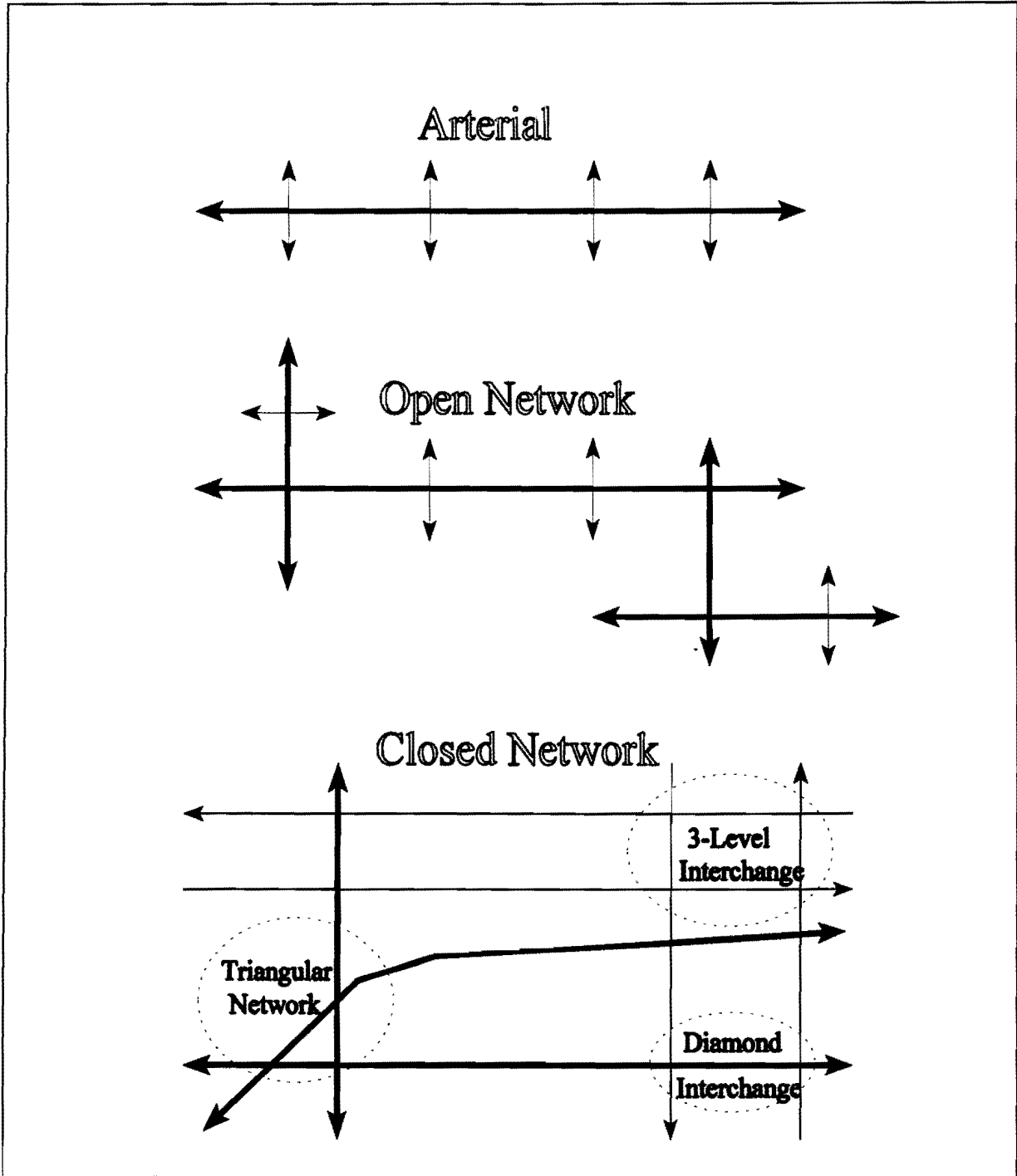


Figure 1: Potential applications of PASSER IV

6. Allows a user to select different measurement units for input data and output report. For instance, the data can be specified in English units, and the output be requested in Metric units. This specific option can be particularly useful in helping the user transition from the English unit system to the Metric unit system.
7. Prints a specified number of best signal timing solutions.
8. Provides an optional search capability especially designed to generate multiple close-to-optimal solutions.
9. Provides one global and two heuristic (2-step and 3-step) optimization procedures.
10. Prints an extensive output report with the name of the output file and page number on each page. The report includes:
 - Input data summary (optional),
 - Optimization performance plot,
 - Network signal timing summary,
 - Artery-by-artery sections including time-space diagrams, and
 - Signal-by-signal NEMA phasing tables and measures-of-effectiveness (MOEs), including: phase intervals, offsets, splits, approach delays, volume-to-capacity ratios, level of service, stops, queue lengths, fuel consumption, and vehicular emissions.
11. Menu-Driven graphic user interface with pull down menus and mouse support. The user interface provides the following additional features:
 - A sub-menu for using the TRANSYT-7F program to fine tune bandwidth-based signal timings generated by PASSER IV. This sub-menu provides functions to run TRANSYT for minimizing network-wide delay and view and print its output.
 - The ability to create and execute batch jobs for making several optimization runs at once. Also included are functions for modifying and deleting these batch files.

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. Detailed descriptions of these categories are provided in the following subsections.

Optimization Data and Run Options

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

Network Geometry, Movement Numbering Scheme, and Offset Reference Point

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

1. Assign a unique node identification (NODID) number to each signal. Identify a master signal to reference the offsets. The offset reference point can be described by specifying a NODID, the direction of master approach (i.e., northbound, southbound, etc.), the choice of either the start or end of the through phase, and a base offset from some other reference point.
2. Assign a NEMA phase 2 number to a selected signal approach. This selection can be different for each signal in the network. The user, however, should use the same geometric direction for all signals in the network when she/he desires to use the bandwidth-constrained delay minimization option using TRANSYT 7F. This restriction is placed by TRANSYT.
3. Assign a priority for each arterial (optional). 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.
4. Assign an A-direction (principal direction) to each arterial. For a one-way arterial, the 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. The A-direction does not imply the direction with higher volumes. The directional priority is specified separately.
5. Select the order in which the arterial will be entered (i.e., assign a sequence number to each arterial in the network). Enter each arterial in this order.
6. Starting with 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 traffic signal.

This scheme implies all the necessary linkage information. The program is able to automatically construct the network structure by using a 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/Software Requirements

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

- A PC with 640K of conventional random access memory (RAM) and 8 megabytes of extended RAM. A minimum of 450K of conventional RAM must be free for running the PASSER IV User Interface. PASSER IV's optimization module runs in extended memory and requires 4 megabytes of RAM.
- A hard disk drive with 2 megabytes 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).
- DOS operating system version 3.1 or higher. The DOS system should be able to open a minimum of 10 files at a time. This is specified in the computer configuration file, "config.sys". Although not specifically designed for 32-bit operating systems, the program will also run from a DOS window under Windows 95 or Windows NT operating systems.

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. PASSR4 can be launched either to optimize the problem specified by the currently loaded data or to optimize a number of problems by using the batch mode. In addition, the UI provides the ability 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 to perform an optimization using currently loaded data,
- Create/execute a batch file for making multiple optimization runs,
- View and print PASSER IV output corresponding to the currently loaded group,
- View and print a specified output file without loading it,
- Display the graph of the network defined in the loaded data file,
- Run T7F program, and
- Edit T7F data, view/print corresponding output, and delete its files.

The PASSER IV UI 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. The left button on the mouse is used to activate various functions and to move to desired input data fields. 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 version and the organization name that the user can change by using the Config option in the File menu. The second line on the screen displays the Main-Menu options.

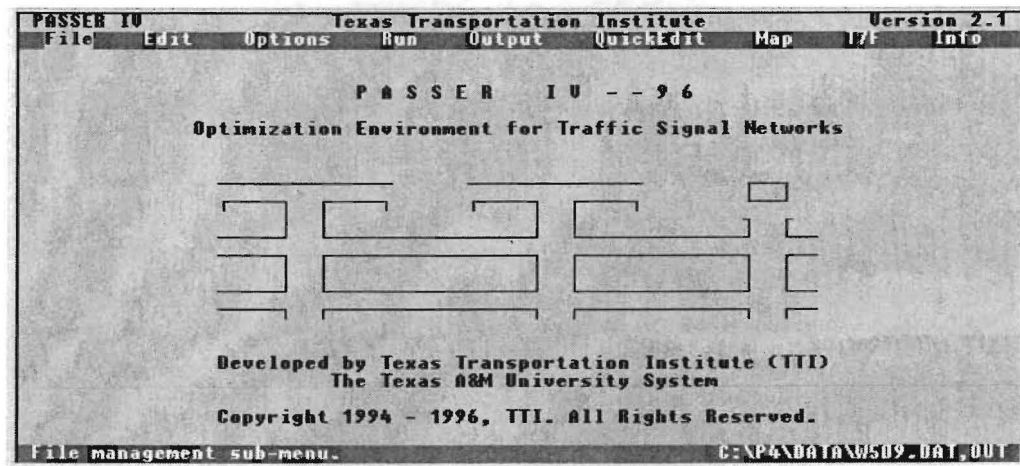


Figure 2: PASSER IV Main screen

Items on the Main-Menu can be selected in one of the following 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:

- Lets the user save modifications on the data file (if necessary), 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. PASSR4 can handle networks with up to 20 arterials and a maximum of 50 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 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 finetune 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 based on a branch-and-bound algorithm. 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 each arterial, and a 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 **Options** item. This section explains concepts related to data used by the MPCODE module in PASSR4. The novice may wish to scan through this section during the first pass. However, it is highly 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 effective utilization of the MILP solution process 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. Furthermore, 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 a LP problem is a relatively trivial task, optimizing a 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 opposing approaches to an intersection, a maximum of four alternate phasing sequences (lead-lag, lag-lead, lead-lead, and lag-lag) may be possible. A set of two binary variables (that can be either 0 or 1) distinguish between these possibilities.

MPCODE uses branch-and-bound (BB) techniques to optimize the MILP problems generated by PASSR4. The BB techniques create a decision tree and make use of a LP algorithm, such as the Simplex method, for solving the Linear Program (LP) sub-problems. The end of a branch on the decision tree may represent 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 a 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 integers, but have non-integer values. A restricted LP is solved at each branch. The search on a branch ends as soon as 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 explicitly or implicitly 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 a LP (total number of variables and constraints), an iteration will require a different amount of computation time (e.g., 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 a 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 a LP can be 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 a 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 problem which may cause the LP algorithm to switch back and forth between two feasible solutions without terminating. Thus, if a LP exceeds the user-selected upper limit on LP iterations, the optimization algorithm terminates. Furthermore, 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 objective function value for the current best solution is 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 a 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 values 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 (tolerance). 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 a 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 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.

Minimizing Cycle Length

Selecting the cycle length minimization flag as "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 user can specify the objective function weight to indicate the importance of cycle length minimization. This will cause generation of the lowest cycle length solution with the best bandwidth efficiency. This ability 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 ability 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 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 (One-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 is selected by setting the number of optimization steps equal to 2. In the first step, it finds the best link and/or network synchronization. It then automatically fixes all synchronization variables 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 Two-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 a one-way arterial and an open network with only one-way arterials. 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 efficiency 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 is selected by choosing the number of optimization steps equal to 3. Best link synchronization is determined in the first optimization step. Using the best link synchronization solution from step 1, network synchronization is determined in the second optimization step. The third step uses the best link and network synchronization 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 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, since this selection will require the least amount of CPU time. For example, the Three-Step optimization procedure is recommended for multi-arterial closed networks with multi-phase signals. The last step of the two heuristic optimization methods (i.e., the phase sequence optimization) requires the least amount of CPU time. Therefore, requesting multiple solutions at the first step of the Two-Step method and only for the second step of the Three-Step method is recommended since this 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 (or efficiencies) 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 some 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.

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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 Three-Step method, use 3 for the solutions to be saved in the third step. When the actual number of solutions found is less than amount requested by the user, reports will be generated for only the best solutions found. Thus, if the user requests 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 and results in excessive CPU time. Furthermore, 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 (One-Step, Two-Step, or Three-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 **O**pen option from the File menu. The following is a description of files in these two categories:

System Files

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

p4.bat: Batch file used to control the execution of PASSER IV. This file passes control back and forth among the UI, PASSR4 and T7F (when applicable). This file resides in a directory from which user wishes to execute PASSER IV.

p4config.sys: PASSER IV configuration file. This file contains user modifiable data and is used by the UI. It contains the path to locate PASSER IV system files, the default path to locate user files, user organization name, a path to locate T7F, the default emissions table name, and three sets of pre-specified tolerances that can be selected from the Options item of the Main-Menu. This file resides in the same directory as *p4.bat* file.

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.

dosxmsf.exe: This file contains the Microsoft DOS extended. It loads *passr4.exe* into extended memory at execution time.

- mrcode*.dat*: MPCODE data file 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.
- mrcode*.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 the user creates and those files that the program creates for his/her use. User files belonging to one group 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 separate directories be used for system and user 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 the user creates. The user can create a new data file by 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 **Save As** option in the **File** menu. When this option is used, the UI assumes the renamed group is 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 user selects the **Run** option 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. A selected output file can be viewed/printed without first loading its group by using the "PreviewOut" function in the **File/Open** sub-menu. An output file can be deleted using the **Delete** option in the **File** menu.

*groupname.ti**: At the user's option, PASSR4 generates these files. 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.til* will generate an output file named *groupname.tol*. 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.

In addition to the files described above, there are two more file types described below.

anyname.bat: This type of file is created using the Batch option in the File menu and is used for making several optimization runs at one time.

othername.tbl: These files contains emissions factors used by the program for calculating emission rates. An emission table may contain emissions data for a specific city or county. The file containing default emissions factors is specified by entering its name in the program configuration file. These factors are then automatically added to any new data file created or any existing data file for the previous version of the program.

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 the A-direction, without skipping any signal. In addition, each signal must be assigned a unique node identification number which the program uses 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.

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The above format is slightly more restrictive than other 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 UI runs in conventional memory and requires a minimum of 450K of free RAM. The optimization routine PASSR4 uses extended memory. We recommend a machine with at least 8 megabytes of RAM. If the required amount of extended RAM is not available, PASSR4 will still run by employing the disk cache mechanism, however, its execution will be extremely slow. In addition, the computer system configuration 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, Version 2.1, can be installed on a local workstation or optionally on a local area network. The following sections describe the steps required for program installation. The manual installation process is described first, followed by a description of the installation program (install.exe) supplied on the distribution diskette. The purpose of describing the manual installation is to provide a better understanding of how various components of the program interact; however, we strongly recommend that the supplied installation program be used for installing the PASSER IV program.

Manual Installation

PASSER IV program and data files are compressed into two self-extracting files (*p4comp.exe* and *p4dat.exe*) supplied on the distribution diskette. These files can be extracted by typing the name of each file followed by pressing the <Return> key. Please note that these files must be extracted onto the hard drive since the distribution diskette does not have enough space to hold all extracted files. Once these files are extracted, manual installation of the program is straightforward, as described below.

1. Deciding and creating the directory from which program will be executed. For example, directory C:\p4.
2. Copying the *p4.bat* file to this directory and setting the program configuration in 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 paths of the system and data directories.

3. Deciding where to store the remaining system files and creating this directory. For example, directory C:\P4\SYSTEM.
4. Copying the remaining system files in this directory.
5. Deciding the name of the default data directory and creating that directory. For example, C:\P4\DATA.
6. Copying all supplied data and emissions tables in this directory.

Installation Program

Although manual program installation is fairly simple, an installation program (*install.exe*) is supplied on the distribution diskette to make the installation process easy for the user. When executed, *install.exe* makes use of *install1.exe* and *install.msg* files provide with it. The installation program can be used to install either a local copy or a network copy of the PASSER IV software. When network installation is selected, the installation program is also copied to the network drive. This copy of the installation program can then be used to install PASSER IV on individual workstations. The installation program performs the following functions:

- Allows the user to specify the names of default, system and data directories,
- If necessary, creates the specified directories,
- Copies configuration, system and data files in selected directories, and
- Modifies the PASSER IV configuration file (*p4config.sys*) to set selected program directories.

Note: The path for T7F is left blank. The user must specify the proper path 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 (e.g., 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 installation type and desired directory specifications. The installation program can be aborted by pressing the <Esc> key.

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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 *p4.bat* and *p4config.sys* 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 presented key features of PASSER IV, explaining what it does, how it works, and how to install it. 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 addition, the preview file can be used to view/print the highlighted output file without first loading it. In the following, we describe how the user should 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.

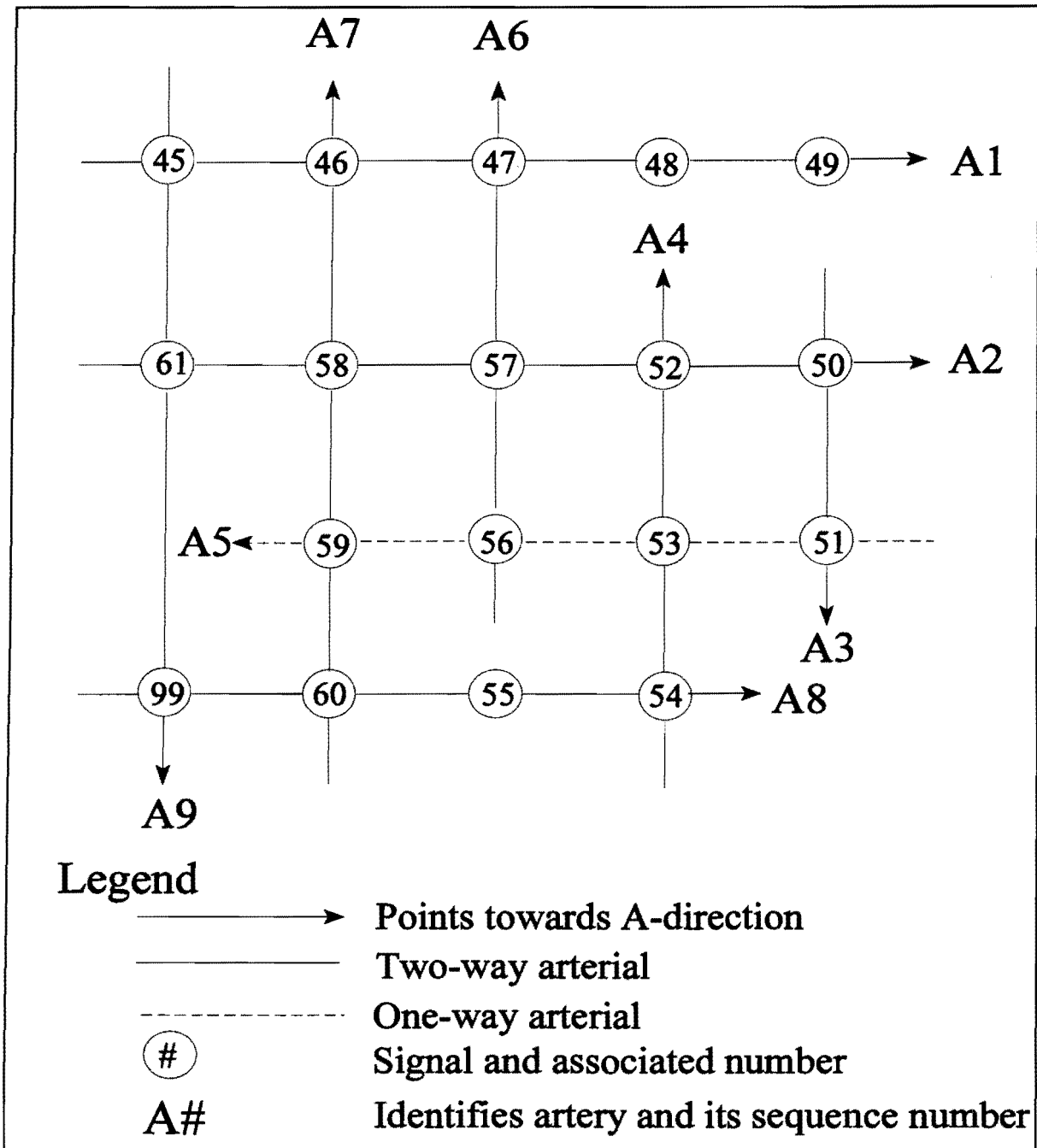


Figure 3: Graph of a sample network

- 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 the approach data, listed below, on the graph:
 - Peak hour volumes or traffic demands.
 - Saturation flow rates (these must be calculated or estimated before using PASSER IV).
 - Minimum splits based on external factors such as pedestrian requirements.
 - Optional green splits, in seconds or fractions of a cycle. If splits are not supplied, they are internally calculated using volume and saturation flow data.
 - Average speeds on, and allowed speed variation between, approach links. Appendix A provides detailed description of these data.
 - v. Identify the set of possible phasing sequences. For minor cross streets, this set should identify only one sequence. 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. Figures 5 and 6 illustrate the two mutually exclusive cases of phasing sequences when an overlap phase is not permitted. The case shown in Figure 5 is also known as split phasing. It should be pointed out that the use of phasing without overlap results in reduced capacity and increases the required cycle length. Therefore, these options should not be used unless warranted by geometric or signal hardware constraints.
3. Use the New option from the File menu to select a *groupname*. This automatically executes the Edit option from the Main-Menu.

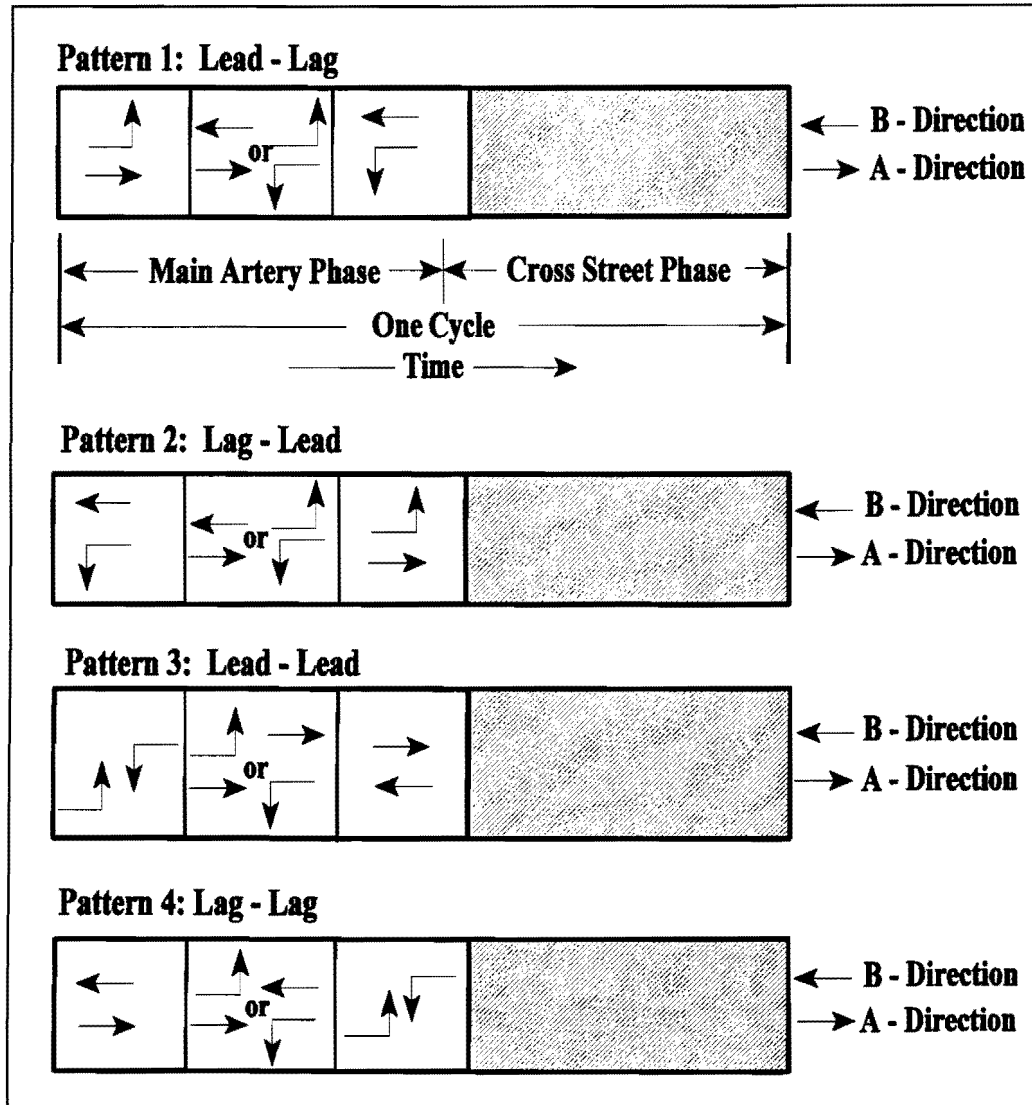


Figure 4: Four possible NEMA phase sequences with overlap

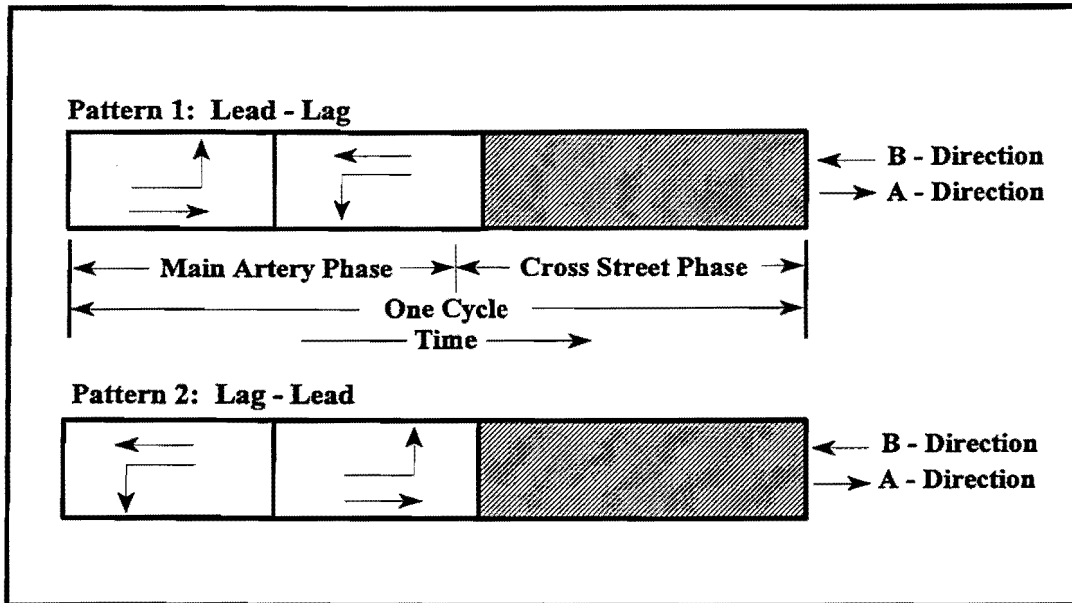


Figure 5: Split phasing sequences

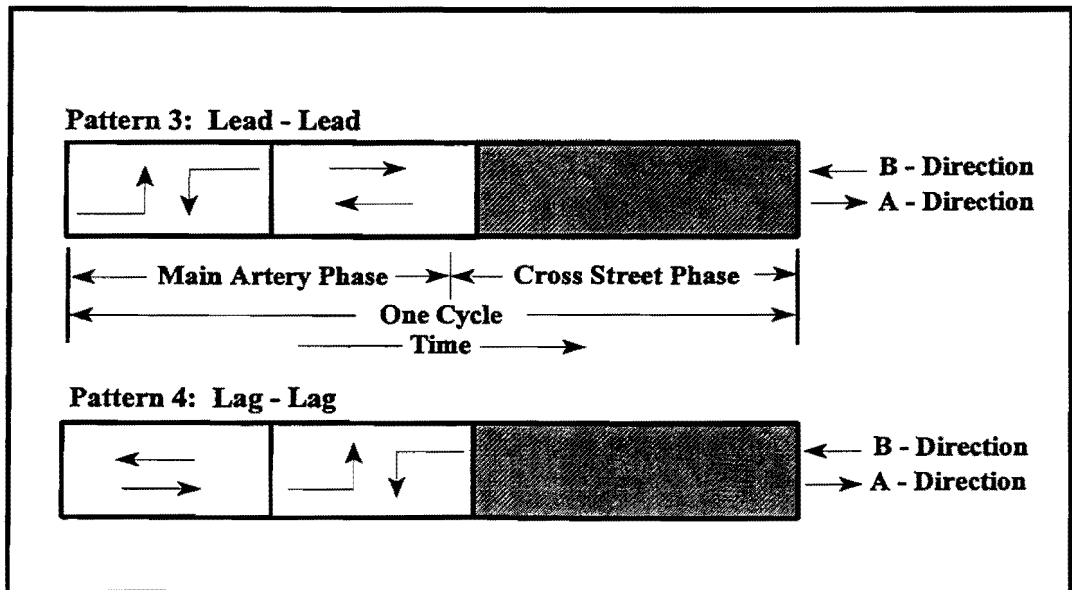


Figure 6: Lead-lead and lag-lag phasing sequences without overlap

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. The System Data Screen lets you enter system wide 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 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.
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

When executed, PASSER IV's optimization routine creates an output file. Each page of this output file contains a header. This header is composed of the output file name, program name and version number, and page number. To view and/or print the PASSER IV output file (*groupname.out*), select the **Output** option from the Main-Menu. Invoking this option displays the output file, if any, corresponding to the currently loaded file group. Several functions are available to allow you to view or print this file. As an alternative, the "PreviewOut" feature in the **File/Open** menu can be used to view/print other output files without loading (opening) their groups. See the Reference section for complete details.

Depending on user selected options in the data, 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 the 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. Furthermore, 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 bandwidth as a fraction of the cycle length, with each band having an associated weight (coefficient).

Solution Report

This section is only printed when the input data does not contain any errors and when the optimization module has found at least one feasible solution. A solution report is printed for each alternate solution saved by the optimization routine. The number of final reports, all included in the same output file, depends on user selection and the number of solutions actually found. A solution report includes:

- Solution summary for each arterial in the network. Figures 7 and 8 illustrate this section of the solution report. The information includes the following:
 - Directional bands in fractions of the cycle length and in seconds.
 - Arterial efficiency and attainability. Efficiency is the percentage of cycle length used for progression of through movements. It is used to describe the quality of progression as: excellent (37%-100%), good (25%-36%), fair (13%-24%), and poor (0%-12%). Solutions with efficiency values of less than 25% are undesirable. Attainability (in fractions) is obtained by dividing the sum of directional bands by the sum of smallest through splits in both direction. Attainability can be graded as: excellent (99%-100%), good (90%-98%), fair (70%-89%), and poor (0%-69%). Excellent attainability indicates that the efficiency can be improved by increasing minimum green times. Good attainability implies that the system must be improved through fine tuning. Attainability values of 69% or lower are undesirable and suggest the need for major changes. These changes may include use of unconventional phasing patterns, breaking progression, and if everything else fails, geometric changes.
 - Optimal phase sequences selected.
 - Optimal travel times and speeds. Please note that these values are selected from the data (ranges of speeds) supplied by the user and are not based on any other analysis. Therefore, it is the responsibility of the user to ensure that the supplied ranges of speeds reflect operating speeds on links.
 - Time-Space diagrams.
- A signal-by-signal solution section which includes:
 - Optimal cycle length.
 - A table containing settings for concurrent phases. These include: phase sequence, phase splits, beginning times of all phase intervals, and offset from the master reference point to the beginning of the first phase interval. Here, phase is considered

to be a time period during which one or more unique and non-conflicting movement(s) has(have) the right-of-way. Offset for a phase can be obtained by adding the phase offset, as a percentage, to the number given in line labeled "Phase Interval (%)" in the column for that phase.

```

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*** ARTERY 3 ***
NAME OF ARTERY:  TORRENCE                    NUMBER OF SIGNALS: 3
A-DIRECTION   :  SOUTHBOUND

*** ARTERY-WIDE INFORMATION ***

ARTERY DIRECTION  BAND (% of Cycle)  BAND (Seconds)
-----
SOUTHBOUND       .3333                      30.00
NORTHBOUND       .2778                      25.00
-----
EFFICIENCY(%):   30.56          ATTAINABILITY(%): 100.00

*** INTERSECTION INFORMATION ***

NODE   CROSS STREET  LEFT TURN PATTERN  SIGNAL
NO.    NAME          SELECTED           NO.
-----
26    ANZA           LEAD- LAG         1
10    HAWTHORNE       LEAD-LEAD        2
27    MADRONA        LEAD-LEAD        3
-----

ALL PHASE STARTING TIMES ARE RELATIVE TO THE START OF E-BOUND GREEN
AT SIGNAL 1 ON ARTERY 1.

** PROGRESSION TIMES AND SPEEDS **

LINK                SOUTHBOUND                NORTHBOUND
-----
<====>            LINK   TRAVEL  AVERAGE   LINK   TRAVEL  AVERAGE
NODE   NODE   LENGTH  TIME     SPEED    LENGTH  TIME     SPEED
NO. <--> NO.   (FEET) (SECS)  (MPH)   (FEET) (SECS)  (MPH)
-----
26 <--> 10    2600.   50.6    35.0    2600.   50.6    35.0
10 <--> 27    2700.   48.4    38.0    2700.   50.0    36.8
-----
ENTIRE ARTERY:      5300.   99.1    36.5    5300.   100.6   35.9
-----

```

Figure 7: Artery Section of Program Output

- Durations (including yellow and all-red times) of NEMA phases, their offsets, and phase reversal information. Offset for a NEMA phase is the time lag between the beginning or ending of that phase from the master reference point. The user selects the offset reference point (beginning or ending of phases). For instance, in Figure 9, the beginning of phases is selected for printing offsets. Phase reversal information informs the user of the optimal phase sequence selected. This concept is explained below.

By default, a dual-ring-8-phase NEMA controller sets lead-lead phasing sequences for both main and cross arteries at a signal. Alternate sequences are specified by reversing the order of conflicting phases on an artery. This concept is illustrated in Figure 10. Here phases 1 and 2 are reversed to implement lead-lag phasing on the main street. This figure also shows a case where the main street has an overlap phase, while the cross street has lead-lead phasing without overlap.

- Measures-of-effectiveness for each NEMA phase. These include: approach delays, delay-based level of service, volume-to-capacity (v/c) ratios, v/c-based level of service, average number of stops, average queues, fuel consumption, and estimates of three types of vehicular emissions.
- A network-wide summary containing bandwidths and efficiencies for each arterial, optimal cycle length, average network efficiency, delay, fuel consumption, and vehicular emissions. Figure 11 illustrates this section.

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 speed of disk drive installed in the computer.

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|---|---|-----------------------|-------|---------|-------|-------|-------|-------|
| *** SUMMARY OF PASSER IV-96 BEST SIGNAL TIMING SOLUTION (CONTINUED) *** | | | | | | | | |
| CYCLE LENGTH = 90.0 SEC | | | | | | | | |
| NODE NO. | 7 : SIGNAL 2 ON ARTERY 2 AND SIGNAL 2 ON ARTERY 4 | | | | | | | |
| | HAWTHORNE (W-E) CARSON (N-S) | | | | | | | |
| | NEMA 2 MOVEMENT : EASTBOUND | | | | | | | |
| ===== PHASE AND CONTROLLER SETTING TABLE ===== | | | | | | | | |
| PHASE SEQUENCE | 1 | 2 | 3 | 4 | 5 | | | |
| NEMA PHASES | 1+5 | 2+6 | 4+8 | 4+7 | 3+7 | | | |
| PHASE SPLIT (SEC) | 10.0 | 40.2 | 25.0 | 4.8 | 10.0 | | | |
| PHASE SPLIT (%) | 11.1 | 44.6 | 27.8 | 5.4 | 11.1 | | | |
| PHASE INTERVAL (%) | .0 | 11.1 | 55.7 | 83.5 | 88.9 | | | |
| PHASE INTERVAL OFFSET (TO START OF INTERVAL 1): 56.9 SEC (63.2%). | | | | | | | | |
| PHASE REFERENCE: START OF E-BOUND PHASE (NEMA #2) AT NODE 25 + BASE= 0. | | | | | | | | |
| ===== MOVEMENT-WISE MEASURES OF EFFECTIVENESS ===== | | | | | | | | |
| NEMA PHASE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| ----- | | | | | | | | |
| SPLITS (SEC) | 10.0 | 40.2 | 10.0 | 29.8 | 10.0 | 40.2 | 14.8 | 25.0 |
| PHASE REVERSAL | \ N / | | \ Y / | | \ N / | | \ Y / | |
| OFFSET(%) TO BEG | 63.2 | 74.3 | 52.1 | 18.9 | 63.2 | 74.3 | 46.7 | 18.9 |
| STOP DEL (SEC/VEH) | 40.1 | 4.1 | 32.1 | 14.8 | 31.6 | 12.4 | 35.1 | 5.5 |
| APPR DEL (SEC/VEH) | 52.1 | 5.3 | 41.8 | 19.2 | 41.1 | 16.1 | 45.7 | 7.1 |
| DELAY LOS | E | A | D | B | D | B | D | B |
| VOLUME (VPH) | 112 | 1622 | 38 | 472 | 34 | 836 | 120 | 284 |
| SAT FLOW (VPHG) | 2400 | 6000 | 1500 | 3000 | 1500 | 6000 | 1500 | 3000 |
| V/C RATIO | .70 | .67 | .38 | .55 | .34 | .35 | .66 | .41 |
| V/C RATIO LOS | B | B | A | A | A | A | B | A |
| LINK LEN (FEET) | - | 1120 | - | 2700 | - | 780 | - | 2400 |
| TRA TIME (SECS) | - | 15.9 | - | 48.4 | - | 11.1 | - | 43.1 |
| AVG SPEED (MPH) | - | 48.0 | - | 38.0 | - | 48.0 | - | 38.0 |
| AVG QUEUE (VEH) | 2.7 | 24.3 | .9 | 8.4 | .8 | 12.5 | 2.6 | 5.4 |
| MAX QUEUE (VEH) | 2.9 | 33.2 | .9 | 10.0 | .8 | 14.5 | 2.9 | 6.0 |
| STOPS (PER VEH) | .92 | .74 | .86 | .76 | .86 | .63 | .86 | .76 |
| UEL CON (GAL/HR) | 48.5 | 50.9 | 28.5 | 35.0 | 44.3 | 38.8 | 30.8 | 29.5 |
| TOT VOC (GR/HR) | 96.9 | 759.3 | 56.4 | 642.3 | 29.5 | 387.7 | 198.6 | 312.0 |
| TOT CO (GR/HR) | 918 | 8332 | 584 | 6908 | 291 | 3976 | 2058 | 3425 |
| TOT NOX (GR/HR) | 66.4 | 1248.8 | 59.0 | 808.6 | 27.6 | 460.3 | 209.3 | 429.1 |
| TOTAL INTERSECTION DELAY (VEH-HRS/HOUR): 13.21 | | | | | | | | |
| TOTAL FUEL CONSUMPTION (GALS/HR): 306.3 | | | | | | | | |
| TOTAL EMISSIONS (KG/HR): VOC: 2.48, CO: 26.49, NOX: 3.31 | | | | | | | | |

Figure 9: Signal timing summary and measures-of-effectiveness section of output

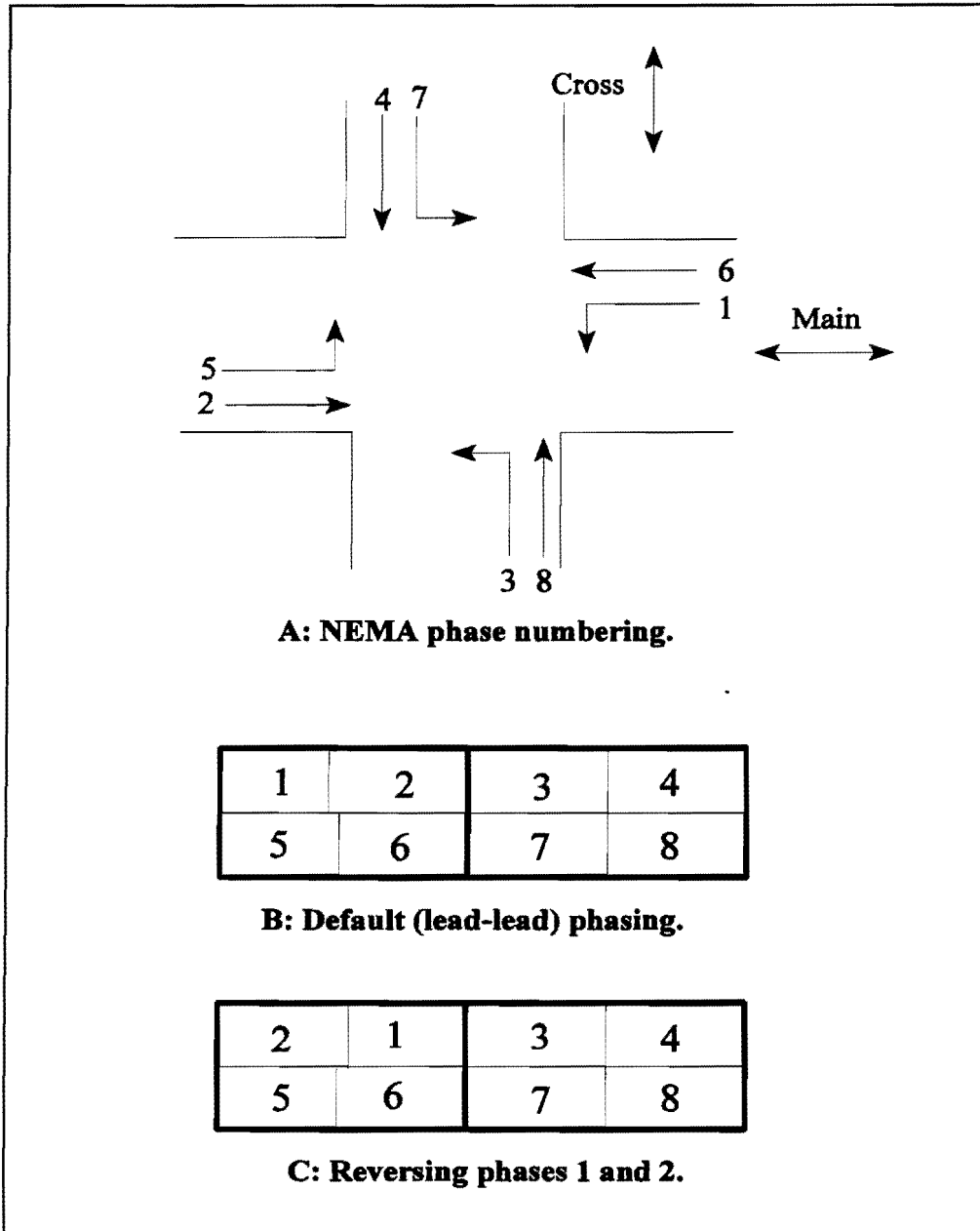


Figure 10: Reversing phases in a dual-ring NEMA controller

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**** NETWORK SOLUTION SUMMARY ****

| | A-BANDWIDTH PERCENT (SECS) | B-BANDWIDTH PERCENT (SECS) | EFFICIENCY PERCENT | ATTAIN PERCENT |
|-----------|-------------------------------|-------------------------------|-----------------------|-------------------|
| ARTERY 1: | EB: 54.93 (49.44) | WB: 55.03 (49.53) | 54.98 | 99.91 |
| ARTERY 2: | EB: 33.88 (30.49) | WB: 16.48 (14.83) | 25.18 | 67.72 |
| ARTERY 3: | SB: 33.33 (30.00) | NB: 27.78 (25.00) | 30.56 | 100.00 |
| ARTERY 4: | SB: 33.15 (29.83) | NB: 25.68 (23.11) | 29.41 | 96.55 |
| ARTERY 5: | EB: 50.82 (45.74) | WB: 50.82 (45.74) | 50.82 | 100.00 |

AVERAGE NETWORK EFFICIENCY : 38.19 Percent
AVERAGE DIRECTIONAL BANDWIDTH: 34.37 Seconds
NETWORK-WIDE CYCLE LENGTH : 90.00 Seconds

NETWORK-WIDE DELAY : 178.24 Veh-Hrs/Hr
NETWORK-WIDE FUEL CONSUMPTION: 1321.16 Gallons/Hr
NETWORK-WIDE VOC EMISSIONS : 18.00 Kg/Hr
NETWORK-WIDE CO EMISSIONS : 182.89 Kg/Hr
NETWORK-WIDE NOX EMISSIONS : 17.35 Kg/Hr

Total Elapsed Time (seconds): 1.10

**** PASSER IV-96 END ****

Figure 11: Last page of PASSER IV output

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's 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 as shown in Figure 12. This screen has several components that are described as follows:

- 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 the network map.

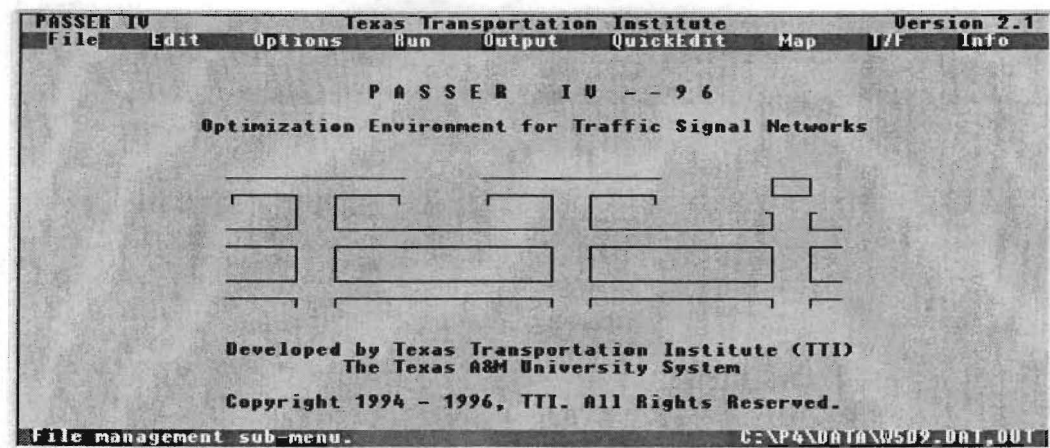


Figure 12: Main screen

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. The user can execute any menu item by pressing the associated hot-key. In addition, from any sub-menu, a Main-Menu item can be selected by simultaneously pressing the <Alt> key and the desired hot-key.

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 ask the user to 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 is assigned the following hierarchical order: system data level, arterial data level, and signal data level. Figure 13 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 the 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 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 Quit the program using the sequence of keys <Alt><X>. The following is a general description of the function keys that let the user move among various data entry screens:

| | | |
|------|---------------------|-------------------|
| <F2> | From Artery screen | To System screen |
| | From Signal screen | To Artery screen |
| | From Phasing screen | To Signal screen |
| <F3> | From System screen | To Artery screen |
| | From Artery screen | To Signal screen |
| | From Signal screen | To Phasing screen |

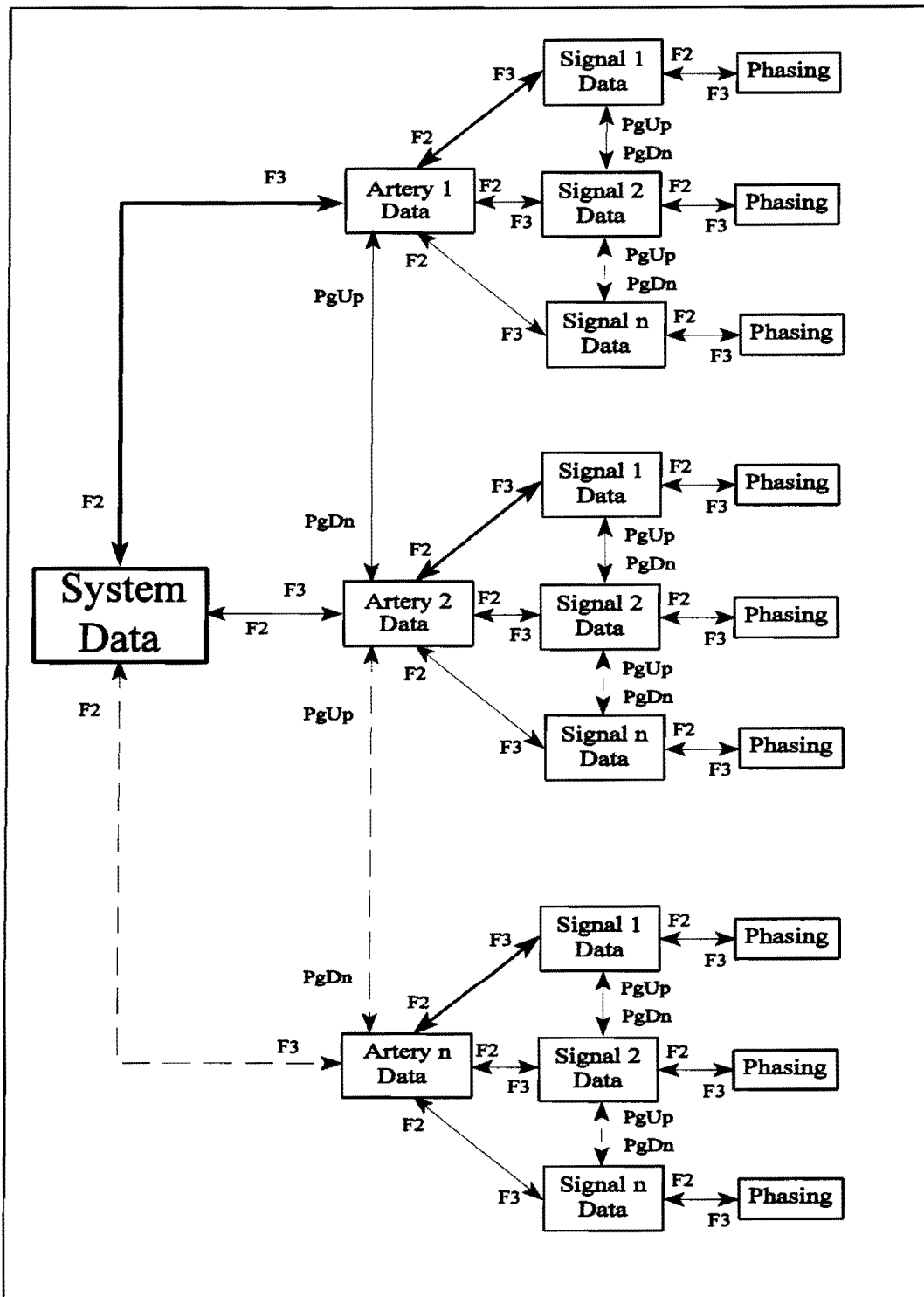


Figure 13: PASSER IV data hierarchy

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

Example: The following sequence of keys will move from the System Data screen to data screen for the second signal on the third 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:

REFERENCE

System Data Screen

This screen is used to enter systemwide data. Figure 14 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.

```
PASSER IV Texas Transportation Institute Version 2.1
Edit
SYSTEM DATA
Run Number : 
District Number : 
Date : 08/21/96
City Name : DALLAS
Network Name : 
Emission Table : DALLAS94.TBL
Number of Arteries : 5
Number of Signals : 9
Lower Cycle Length (Sec) : 90
Upper Cycle Length (Sec) : 90
Units (E/M) Input: E Output : E
Systemwide Lost Time (Sec) : 60
*** MASTER SIGNAL OPTIONS ***
Master Signal Id. Number : 
Offset to Master Signal : 
Master Approach Direction : -B
Offset to Begin/End of Green : 
*** OUTPUT OPTIONS ***
Print Input Data Summary (y/n) : N
Print Warning Messages (y/n) : N
Optimize Signal Timings (y/n) : Y
Esc:End F3:Artery
Run Number: Optional. C:\P4\DATA\MS09.DAT,OUT
```

Figure 14: System data screen

Mandatory Data

This data is required by the program. Some of this data is referred to as the skeleton data which defines 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 mandatory data.

- Number of Arteries (skeleton data)
- Number of Intersections (skeleton data)
- Lower Cycle Length
- Upper Cycle Length
- Units for input data
- Units for output report
- Systemwide Lost Time
- Print Input Data Summary
- Optimize Signal Timings

Notes:

1. A system can have 1 to 20 arterials and 2 to 50 signalized intersections.
2. The 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. The systemwide lost time range is three to five seconds. It is used in green split and delay 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. The default value for lost time is four seconds.
4. Different units for input data and output report are permitted. For instance, the data can be in English units (e.g., distances in feet and speeds in miles per hour) and the output requested in Metric units (e.g., distances in meters and speeds in kilometers per hour). This capability will allow easy transition from English units to the Metric system of measurement. The default selection for input data is English. The output units default to the same as input data units. Therefore, when different units are desired for input data and output, specific values must be entered in these fields.
5. Request for Input Data Summary and Optimize Signal Timings are related fields. One of these options must be selected as Y (yes). Running PASSR4 always perform checks on input data. In case of data errors, the program attempts to proceed as far as possible. Each error generates a self-explanatory message. When input data is successfully read, the following actions are taken based on user selections:

| No. | Summary? | Optimize? | Action and Output File (<i>groupname.out</i>) Contents |
|-----|----------|-----------|---|
| 1 | Y | N | Data summary section is printed. Optimization is not performed. |
| 2 | N | Y | Data summary section is not printed. Optimization is performed, and solution report is generated. |
| 3 | Y | Y | Data summary section is printed. Optimization is performed, and solution report is generated. |

Furthermore, output option number 1 (Y for Summary? and N for Optimize?) is automatically selected when a new data set is created using the New option from the File menu.

REFERENCE

Optional Data

Most of this data is used for descriptive purposes and printed, as entered, in the PASSR4 output file (*groupname.out*). The following is a listing of all optional data:

Run Number
District Number
City Name
Network Name
Date
Emissions Table
Master Signal I.D. Number
Master Approach Direction
Offset to Master Signal
Offset to Begin/End of Green
Print Warning Messages
Generate T7F Data File

Notes:

1. The date is entered in a group of three two-column fields (month/day/year). When new data is entered using the New option of File sub-menu, the system date is automatically entered in these fields.
2. An emissions table contains factors for estimating three different types of vehicular emissions: volatile organic compounds (VOC), carbon monoxide (CO), and oxides of nitrogen (NO_x). The values of these factors include emissions rates in grams per hour for an idling vehicle and in grams per mile of travel for a range of average travel speeds. Please note that regardless of the units selected for other data, the emissions factors are always in grams per hour and grams per mile. The user can select an existing emissions table by typing its name in the field provided on the System Data screen. However, the selected table must reside in the user specified data directory. More detail on emissions tables is supplied in the section describing the File option of the Main-Menu. The emissions estimation procedure used in PASSER IV is described in Appendix B.
3. By default, the start of A-direction through green for the first signal on the first arterial is used as the zero reference point for all offsets. A set of three data items is provided for and allows the user to select a different reference point: (i) Master Signal Identification Number specifies the master signal, (ii) Master Approach Direction (e.g., N-bound) identifies one of the four through movements as the master direction, and (iii) Offset to Begin/End of Green specifies the beginning or ending point of the master direction through phase as the reference point. Offset to Master Signal selection is provided to allow the user to set the master reference point to a value other than zero. This can be particularly useful in time-based coordination. The value entered for this last data is assumed to range from zero to the cycle length.

4. Warning messages are generated when a data item is not correct, but the data item can be corrected using default values.

Artery Data Screen

The Artery Data screen, illustrated in Figure 15, is used to enter artery-wide data for each arterial. The label in the middle of the top border identifies this screen. The top border also 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.

| ARTERY 1 DATA | | | | | |
|--|---|--------------------|--------------------|---|---------|
| 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 Variation | : | 3.0 | | | 3.0 |
| Speed Change | : | 3.0 | | | 3.0 |
| F2,Esc:System PgUp:Prev PgDn:Next F3:Signals | | | | | |
| Artery Name: Optional. | | | | | |

Figure 15: Artery data screen

Mandatory Data

This data includes 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. The following is a list of all mandatory data:

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

REFERENCE

Notes:

1. The 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). For a two-way arterial, the B-direction is automatically chosen by the program to be the direction opposite to the specified A-direction. The value entered in this field identifies the default directions for reading the traffic data for all signal approaches corresponding to direction(s) on the current arterial. This field cannot be left blank.
3. Time scale units are the number of seconds per character. This number is used for generating a time-space diagram. If the field is left blank, a value of 3 is initially assumed by default. In any case, if the given or assumed number is not sufficient to show full progression bands, this number is changed by the program later. When this happens, a warning is printed in the header section of the time-space diagram to inform the user that the scale has been modified.
4. Distance scale units are feet per line or meters per line depending on whether the user selects English or Metric units for the output. 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.
5. Artery priority determines the relative importance of current arterial in relation to all other arterials in the network. The range of this field is from 0 to 101, as described below:

| Priority | Action/Interpretation by the program |
|-----------------|---|
| 0 or blank | No priority constraints used. Results in smallest MILP formulation. |
| 1-100 | Specified priority is used. |
| 101 | Priority is calculated using total volumes on the arterial. |

It should be kept in mind that the specified priorities are merely target values that are loosely enforced. For instance, if the priorities for arterials 1 and 2 are 5 and 10, respectively, the optimal bandwidth efficiency for arterial 2 will not necessarily be twice that of artery 1. This is due to the fact that there are other constraints (e.g., the smallest green time and bandwidth interference) that restrict the maximum efficiency of an artery, and it is not proper to restrict the band for an artery just to maintain the specified priorities. Thus, in the above example, bandwidth for artery 1 will not be forced to remain half of that for artery 2 once the maximum possible band for artery 2 has been achieved and a larger band for artery 1 is possible.

6. For an arterial, directional priorities specify the importance of one flow direction over the other. In addition, these are also 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, the value of that field 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). In addition, like artery priorities, directional priorities are also loosely enforced for to the same reasons described in item 5 above.

7. Average directional speed, Variation, and Change values must be supplied for at least one direction. If a field is left 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 Variation 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 Variation 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 this data is provided in Appendix A.
8. The status line gives us the information about the default value and range of values for the filed pointed by the cursor.

Optional Data

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

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 Data screen. Figures 16 shows the Signal Data screen.

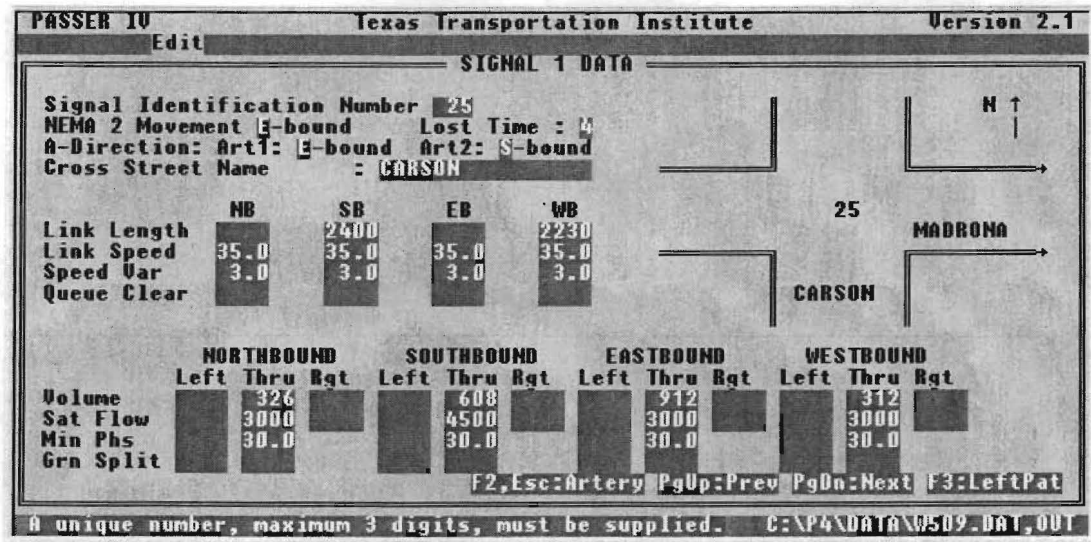


Figure 16: Signal Data screen

The top border of the Signal Data screen identifies the current artery that the 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 the current 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 Data screen:

Mandatory Data

- Node Identification Number (skeleton data)
- Direction of NEMA 2 Movement
- A-Direction for the current artery (Art1)
- A-Direction for the cross artery/street (Art2)
- Link Lengths
- Volumes
- Saturation Flow Rates

Optional Data

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

Notes:

1. 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 a signal identification number for a signal, however, is arbitrary.
2. The NEMA 2 movement direction must be entered. This is used to assign numbers to phases printed in 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. To reduce confusion, however, it is recommended that the user assign each signal the same direction as NEMA 2 when the user wishes to perform further analysis using T7F.
3. Lost time, link speed, and speed variation for the current signal are given if they are different from the systemwide/arterywide values entered previously.
4. The A-direction for artery 1 (Art1) identifies the directions for reading the approach data for that arterial. On this screen, Art 1 is referred to as the arterial corresponding to the Artery Data screen from which this screen was accessed using the <F3> key. When this screen is accessed from the Map option on the Main-Menu, however, Art1 always refers to the artery which was defined first. By default, the A-Direction for Art1 is the direction entered on the Artery Data screen.

The A-direction for artery 2 (Art2) defines the directions from which approach data will be read for the cross artery or minor cross street approaches on the current signal. For a major cross artery that has at least one more intersection connected to this signal, the default value for this field is the value of the A-direction entered on the Artery Data screen for that artery. If this field is left blank for a minor cross street, the program assumes this direction to be the direction of movement at the signal approach next to the A-direction for Art 1, using clockwise rotation. As an example, if the A-direction on the current artery is northbound, eastbound will be assumed for this field. However, in order to minimize confusion, the user should enter the desired value.

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The A-directions for the two arteries and the NEMA 2 direction at an intersection are needed to assign NEMA numbers to geometric directions for printing the signal timing tables.

In certain circumstances, the default values for the A-directions may need to be changed in order to ensure correct placement of approach data for the signal. One such case is a triangular network or subnetwork such as that shown in Figure 17.

The network shown in Figure 17 is composed of three arteries labeled A1 (entered first), A2 (entered second), and A3 (entered last). Artery 1 has three signals and runs east-west. The A-direction for this artery is selected to be eastbound (indicated by an arrow). Please note that northbound and southbound approaches on signal 2 will be referred to as minor cross street approaches. Arteries 1 and 2 are both assumed to run north-south with southbound A-directions. This causes a problem at signal 4 since the A- and B-direction approach data for both these arterials cannot be read from the same fields. Thus, the A-direction for one arterial at signal 4 must be changed and data for its approaches entered in the appropriate data fields. For instance, assume that you wish to keep the default A-direction for the artery 2 approach at this signal. Then, the A-direction for the artery 3 approach will have to be changed. As long as data for the two approaches is entered in the correct fields, you can use either eastbound or westbound; however, in order to reduce the chances of creating confusion, we strongly recommend using the consistent direction. In this case, the consistent direction is westbound. Had we decided to change the A-direction of the approach on artery 2, we would have used eastbound.

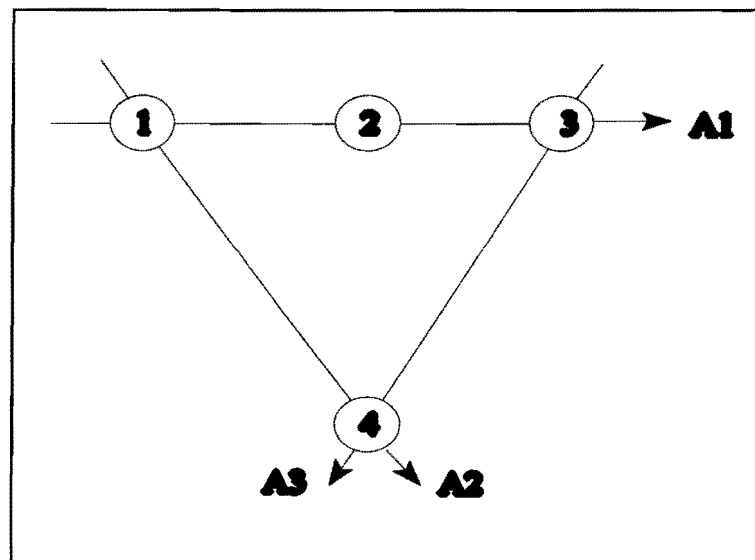


Figure 17: Example of a triangular network

5. 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. When data is entered in seconds, it is automatically converted to fractions of a cycle using the lower cycle length limit the user supplies.
6. 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.
7. Either green splits, or volume and saturation flow rates must be given. If splits are given, they are used regardless of the volume and saturation flow rates. Otherwise, volumes, saturation flow rates, and lost times are used to calculate green splits using Webster's method.
8. If volumes are not supplied, measures-of-effectiveness are not calculated. In addition, the TRANSYT 7F data file will be incomplete.
9. 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. When a left or right movement shares a through lane, corresponding movement volumes are added to through lane volumes by the program.

The pop-up window, shown in Figure 18, allows the user to choose possible phasing sequences for the current signal, from which the program will select the optimal sequence during optimization. Here, the user must first choose one of the overlap/no-overlap cases. Figures 4, 5 and 6 (pages 23 and 24) in the *Getting Started* section illustrate these cases. These three cases are as follows:

- a) Phasing with overlap, selected by leaving the field blank or by entering a 1,
- b) Split phasing, selected by entering a 2, and
- c) Lead-lead or lag-lag without overlap, selected by entering a 3.

The user then chooses all or a sub-set of the applicable options. A phasing sequence option is chosen by entering a "Y" in front of a specific option. An "N" can be typed for all non-applicable options. By default, an "N" is assumed. The following is a list of options for the current artery and cross-artery/street when phasing with overlap is permitted:

- 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, and
- iv. A-direction left-turn lags and B-direction left-turn lags.

When the no-overlap scenario is selected, the above set of phasing sequences splits into two mutually exclusive sets. The first set includes options (I) and (ii) which are applicable to the split phasing case. The second set is composed of options (iii) and (iv) which only apply to the lead-lead or lag-lag phasing without overlap.

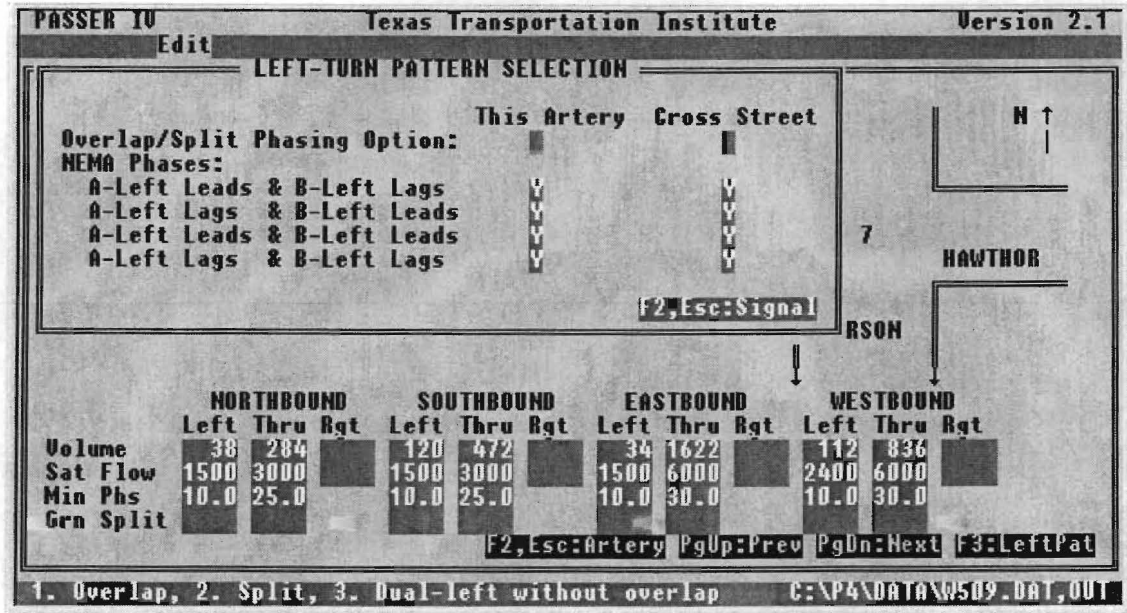


Figure 18: Pop-up window for phase sequence selection

Notes:

1. The user can only 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. In addition, the no-overlap case become the same as the overlap case.
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 a minor cross street, exactly one option (identifying the existing phasing) 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 in the output report.

FILE SUB-MENU

The File option of the Main-Menu provides a number of options. These include options for managing user files. For detailed information about these files, please refer to the *User Files* section on page 16 of this manual. Figure 19 shows this sub-menu. Items on this sub-menu are described as follows:

Open/preview <F4>

The Open/Preview option allows the user to load (open) an existing file group or view/print a selected PASSER IV output file (*.out). 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 the user selects this option, the program displays a window showing the existing PASSR4 data (.dat) and output (.out) files. See Figure 20 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.

A file group can be selected (shown as highlighted) by using the arrow keys or by moving the mouse pointer to a file name and clicking the left button (pointing and clicking). Once a file is selected, it can be viewed by selecting the preview button at the bottom of the window. This can be done by pressing the <F3> key on the keyboard or by using the mouse. A highlighted file group is loaded by either pressing the <Enter> key or by clicking the mouse button.

The list of T7F data and output files corresponding to the currently loaded *groupname* can be viewed from the T7F menu by selecting any one of the available options.

Save <F5>

The “Save” option saves the currently loaded/edited PASSR4 data file (*groupname.dat*). This option is automatically provided when the Run, QuickEdit, or Exit option is selected from the Main-Menu..

SaveAs <F6>

The “SaveAs” option saves the current data file (*groupname.dat*) with a different user-specified name (e.g., *newname.dat*). It also changes the current (loaded) group name to the *newname*. The user can use this option to create several alternate cases for the same basic data set.

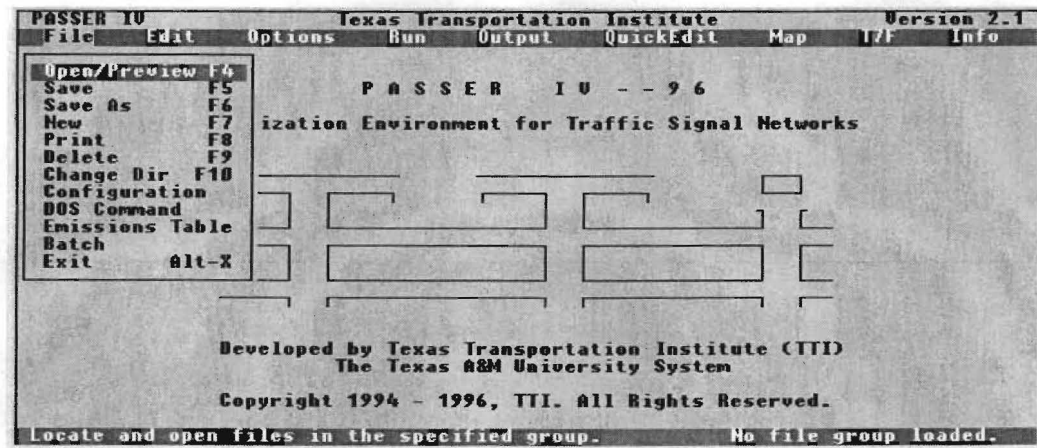


Figure 19: File sub-menu

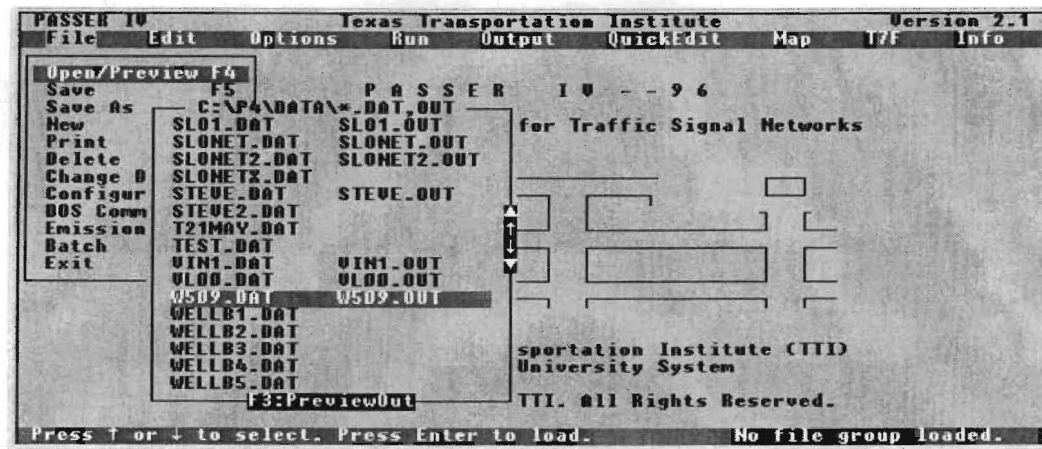


Figure 20: Window showing a sub-set of existing files

New <F7>

The “New” option lets the user select a new, previously unused, *groupname*. After a new *groupname* has been entered, the program automatically executes the **E**dit function of the Main-Menu, which allows the user to create the PASSR4 data (*.dat*) file corresponding to the new *groupname*.

Print <F8>

The “Print” option prints a specified file. This is a generic print function that can be used to print ASCII files such as PASSER IV user files.

Delete <F9>

The “Delete” option 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>

The “Change Directory” option 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 the ability to use files stored in alternate directories or drives, than that specified in the configuration file, without having to change the system configuration.

Configuration

The “Configuration” option is 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. Program Path. This is where system files for PASSER IV are located.
3. Data Path. Default path for user files.
4. User Path. This is the location from which PASSER IV is launched.
5. Emissions Table. This is the name of emissions table that will be automatically added to the data files. It is assumed that emissions tables are located in the same directory as data.
6. Location of TRANSYT-7F program. If blank, it is assumed that TRANSYT is not available.
7. Three sets of alternate tolerance values, any one of which can be selected from the **O**ptions screen of the Main-Menu by using the <F1> key. These are used by MPCODE, the optimization module of PASSR4.

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DOS Command

The "DOS Command" option allows the user to execute any DOS command without exiting the program. Sufficient memory must be available to allow the use of this feature.

Emissions Table

A user-selected table containing emissions factors is used by PASSER IV to calculate estimates of three types of vehicular emissions. The vehicular emissions estimated for each signal timing solution are; volatile organic compounds (VOC), carbon monoxide (CO), and oxides of nitrogen (NOX). Details of the emissions estimation procedure are provided in Appendix B. The "Emissions Table" sub-menu, illustrated in Figure 21, provides the following options that allow the user to work with these tables:

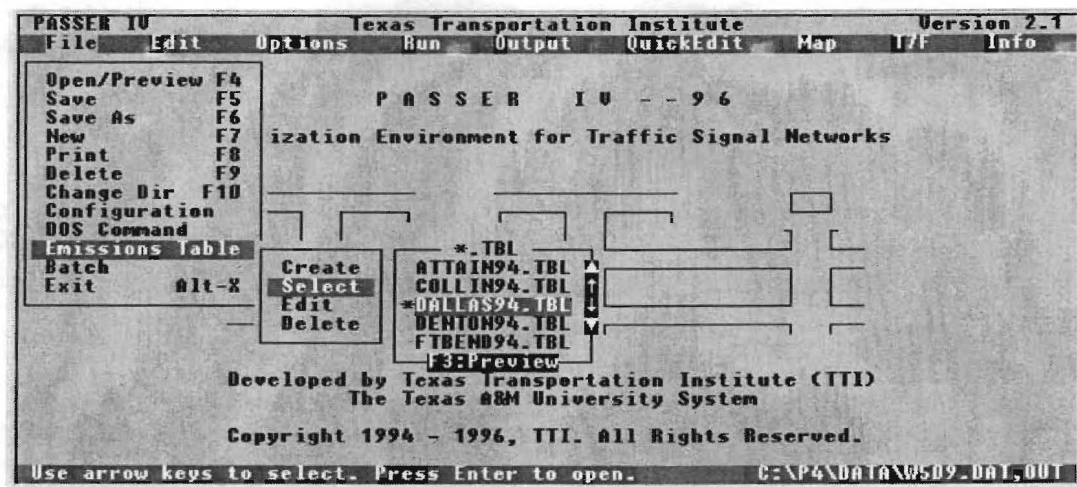


Figure 21: Emissions table

Create

Create allows the user to define a new table. When this option is selected, the user is asked to enter a name (without any DOS extension) for the table to be created. Once a name has been entered, a blank form is displayed for entering the information. Optional information on this form includes County name and year. Mandatory information includes: (1) rates of emissions, in grams per hour, of the three types of emissions for an average vehicle when it is idling, and (2) rates of emissions, in grams per mile, of the three factors when an average vehicle is traveling at a certain speed. This data is specified for a range of speeds from 5 mile per hour (mph) to 55 mph in increments of 5 mph.

Select

Select allows the user to select a table other than that specified in the configuration file. When this option is selected, a list of available tables is provided from which the user can make a selection. The user can also view information contained in a table by using the preview button.

Edit

Edit allows a user to view or edit information in an existing table.

Delete

Delete is used to remove an existing table.

Batch

At times, a user may wish to optimize several problems in a single run. These may be alternate cases for the same problems or unrelated problems. The Batch option in PASSER IV provides this capability. When this option is selected, the sub-menu illustrated in Figure 22 appears. The four sub-menu items are described below.

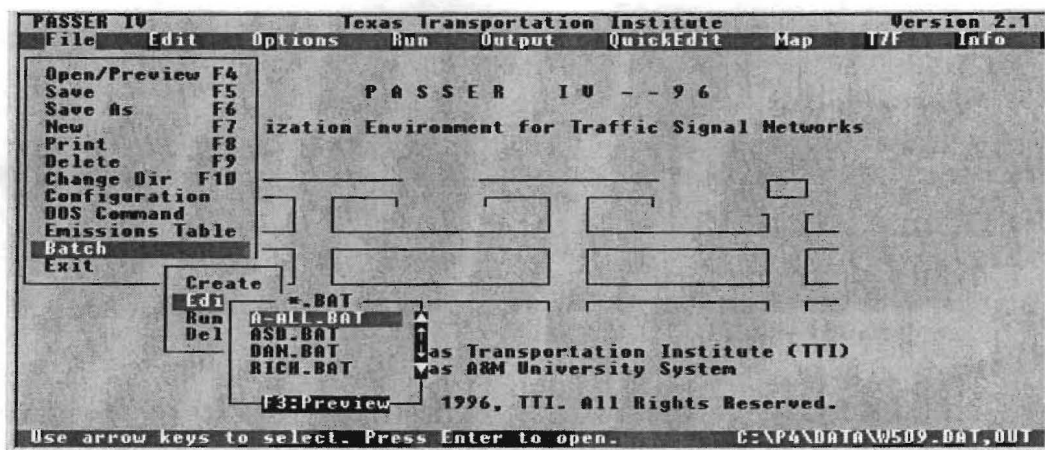


Figure 22: Batch processing feature of PASSER IV

Create

Create allows the user to define a new batch file. When this option is selected, the user is asked for a name. Once a name has been selected, all data files in the current data directory are listed. The user can select files by using the arrow key followed the <Enter> key, or by pointing and clicking

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the mouse. An asterisk (*) is placed in front of the selected files. The user can also unselect one or more files using the same procedure as that for selecting the files. The <F4> key is used to finish the file definition. The batch file is then stored in the data directory.

Edit

The **Edit** option provides the ability to edit existing batch files. When this option is selected, a list of existing batch files is displayed. Then, the user can select one of displayed files and edit (e.g., add or delete data sets) by using the same procedure described above. When a mouse is used, click to highlight a file and click again to activate the Edit function.

Run

The **Run** option allows the user to execute an existing batch file. When the user chooses this option, a list of existing batch files is displayed. The user can then select one of the files and execute it by clicking the mouse button on the selected file a second time.

Delete

Delete allows the user to remove existing batch files.

Exit <Alt><X>

This option (**Exit**) allows the user to exit PASSER IV. At any time and from anywhere in the program, the user can exit 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*.

Concluding Remarks

Pressing the highlighted letters, or using arrow keys followed by the <Enter> key will invoke the desired sub-menu item. The function keys (e.g., <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 **F**ile menu or the **M**ain-Menu.

INFO SUB-MENU

Info sum-menu provides general information about the PASSER IV program. First time users are strongly encouraged to read this information. This Main-Menu option has the following sub-menu:

Rights

Choosing this option (**Rights**) displays the copyright information and outlines the user responsibilities.

PASSER IV Files

This option displays the names and descriptions of PASSER IV files.

Menus & Keys

This option provides general information about the various keys and their function.

Data Entry

This option describes the general data entry scheme.

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MAP

This Main-Menu option (**Map**) lets the user view the map of the network defined in the currently loaded data file *groupname.dat*. When a map is too large to fit on a single screen, only the top-left section of the map is initially displayed. The user can use the <Ctrl> key together with one of the arrow keys to view other sections of the map. Figure 23 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 arterials are drawn using solid lines, while one-way arterials are drawn using directional arrows showing the one-way direction flow. Arteries are identified by the sequence numbers assigned to them in the order the arterial data is entered. The A-direction of an artery is indicated by placing the artery identifier (e.g., 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 the order (6-7-8-9-10), is eastbound. Thus, A2 is placed to the east 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, arterials forming a triangular network, a rare case, cannot be displayed properly.

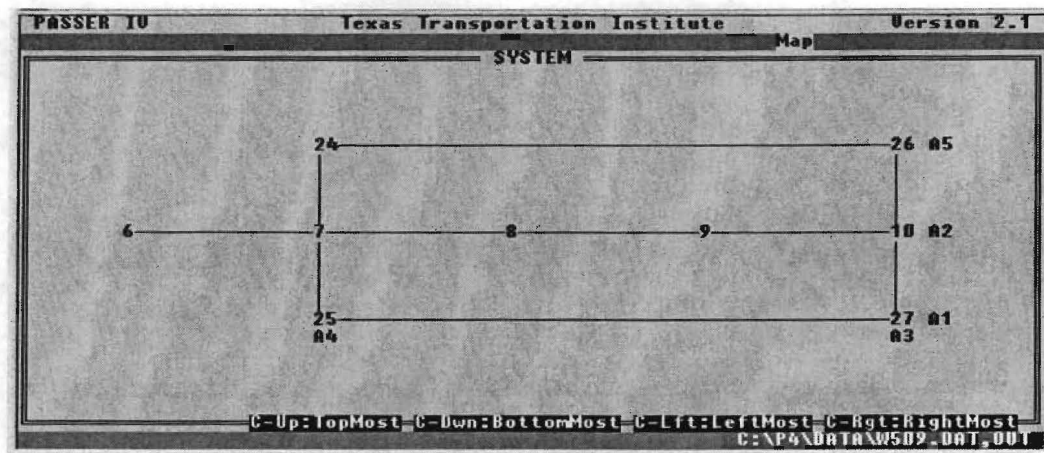


Figure 23: Map screen showing the graph of a sample network

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 the 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. Network name or the word SYSTEM, when a network name has not been specified, 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 (Art1). Pressing the <Esc> key or the right button on the mouse brings you back to the Map screen. For networks with arterials running horizontally and vertically, 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 (e.g., adding or deleting arteries and signals) using the **QuickEdit** option, and
2. Select the **Map** option and select entities to enter the traffic data.

OPTIONS

Selecting Options from the Main-Menu displays the screen illustrated in Figure 24. This screen 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.

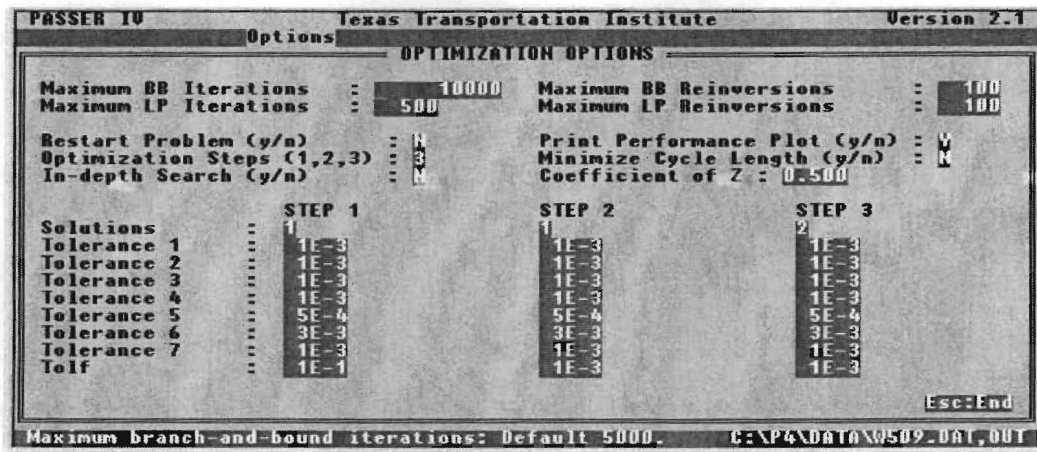


Figure 24: Optimization data screen

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 integrality constraints (synchronization and phasing sequence selection), the BB algorithm is complete. If not, the BB algorithm starts creating a decision tree by adding integrality constraints. At each branch a LP is solved. When a feasible signal timing solution better than the current best 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 a LP algorithm is predictable. In rare events, a 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 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. The user specifies maximum BB iterations in order to tell the algorithm to stop when the specified limit has been reached.

At the end of a 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 (e.g., 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 beyond a certain limit, however, are 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 one 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

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Notes:

1. The upper limits on iterations and re-inversions set as defaults 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 only be 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 (one-step) or heuristic (two- or three-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 | One-step |
| Single arterials and open networks with left-turn phases | One- and two-step |
| Closed loop networks with one-way arterials only | One-step |
| Closed loop networks with no left-turn phases | One- and two-step |
| Closed loop networks 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 user to select 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 25 and 26 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. A description of keys used for moving around in the output file and for printing sections of this file is given below. A detailed description of PASSER IV output is provided in the *Getting Started* section.

| | |
|--------------|--|
| <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. |
| | Go to the previous sub-section. |
| | Go to the next sub-section. |
| <S> | Go to the previous section. |
| <s> | Go to the next section. |
| <r> | Go to the next alternate solution, if any. |
| <R> | Go to the previous alternate solution, if any. |
| <F6> | Print Menu. Sub-menu items are described as follows: |
| <P> | Print this page. |
| | Print this sub-section. |
| <S> | Print this section. |
| <F> | Print whole output file. |

REFERENCE

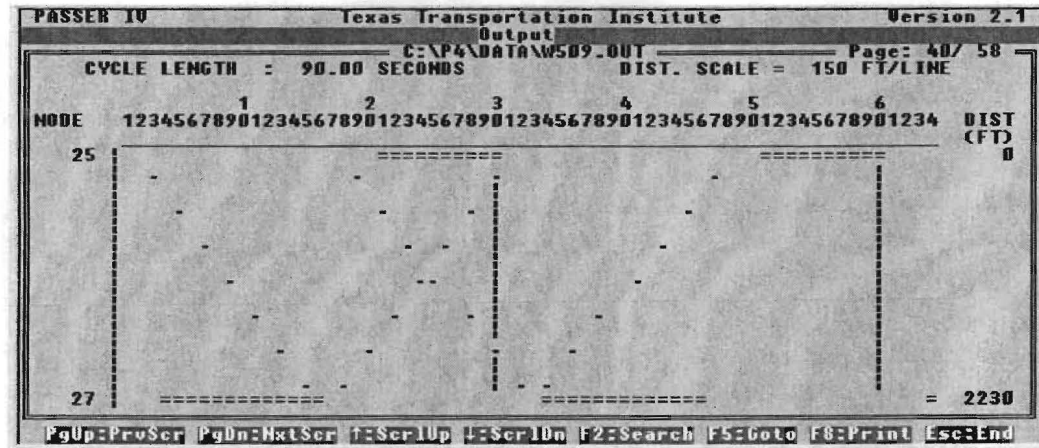


Figure 25: Output window showing a time-space diagram

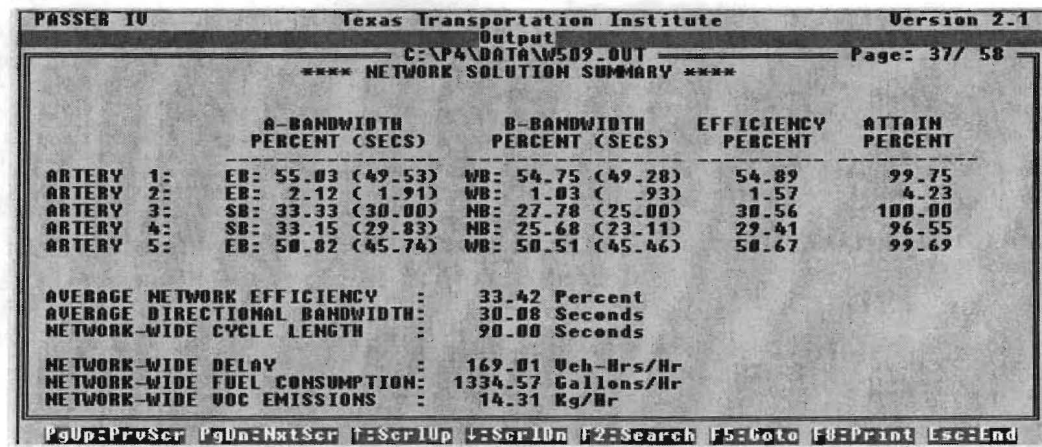


Figure 26: Output window showing network solution summary

QUICKEDIT

As described in the *Getting Started* section, PASSR4 reads the data file (*groupname.dat*) the user creates. Whereas the Edit feature allows you to view 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, the program invokes a built-in text editor and loads the data file for editing. Figure 27 illustrates the text editor window.



Figure 27: Text editor screen

The line at the bottom of the text editor screen lists the functions provided by the text editor. These functions are described below.

- 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 press 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. Keep the mouse button pressed and move the mouse to define the block, and
 3. Release the mouse button.

REFERENCE

- Saving the file: Pressing <F9> saves the changes to the currently loaded file. Pressing <F10> saves the file with a new name the user specifies.
- 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 PASSER IV input data file is given in Figure 28.

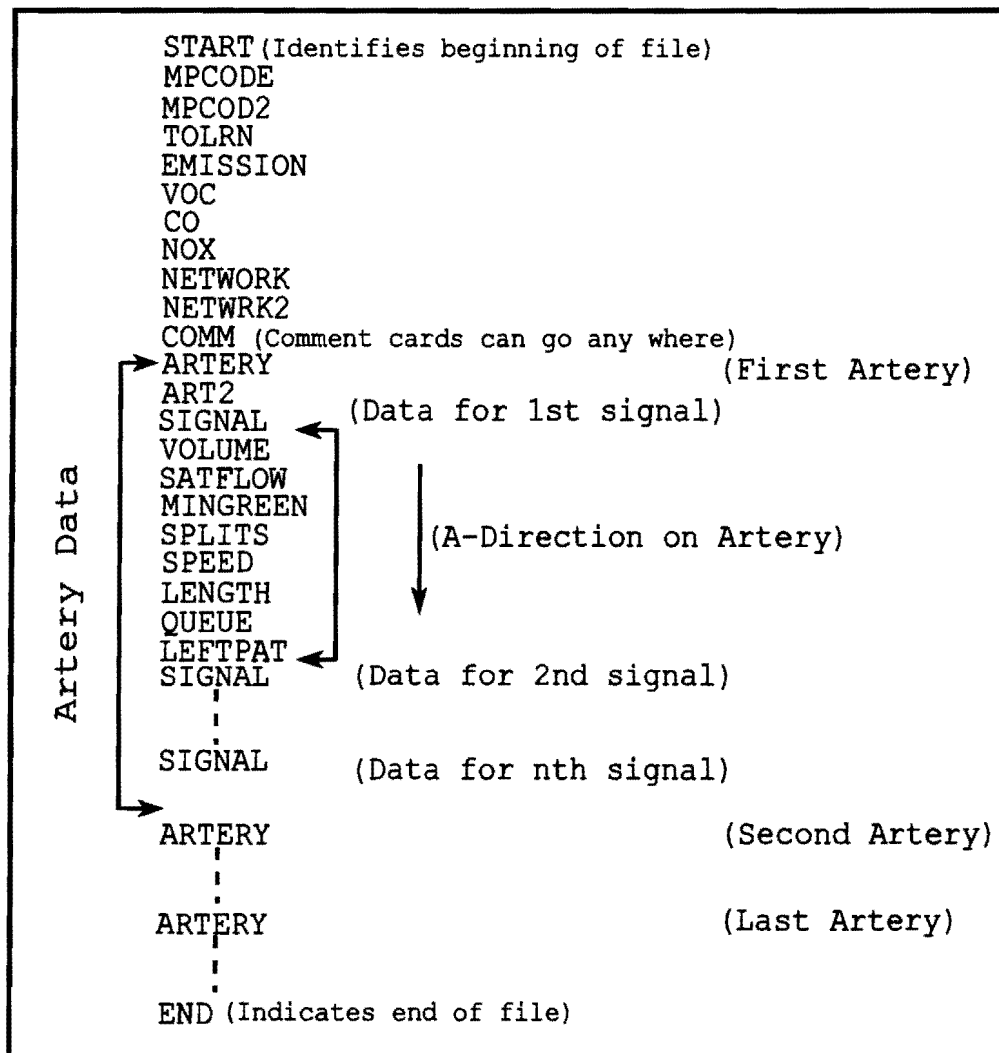


Figure 28: Structure of PASSR4 input data file

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. A detailed description of information on this card follows:

Warning Level (Integer)

| | | |
|---------------|---|--------------------------------|
| Columns 16-20 | 0 | Print warning messages. |
| | 1 | Do not print warning messages. |

Output Level (Integer)

| | | |
|-----------|---|---|
| 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 (Alphanumeric)

Columns 21-25 (optional data)

District Number (Alphanumeric)

Columns 26-30 (optional data)

Date (Integer:Integer:Integer)

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

City Name (Alphanumeric)

Columns 41-63 (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 (Integer)

Columns 11-20

Maximum Branch and Bound Re-inversions (Integer)

Columns 21-25

REFERENCE

Maximum Linear Program Iterations (Integer)

Columns 26-30

Maximum Linear Program Re-inversions (Integer)

Columns 31-35

Restart This Problem (Integer)

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

Print MPCODE Performance Plot (Integer)

| | | |
|-----------|---|--------------------------------|
| 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 (Integer)

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

Solutions Saved In Step-1 (Integer)

Column 20; Range 1 to 5.

Solutions Saved In Step-2 (Integer)

Column 25; Range 1 to 5. Only valid for Two-Step and Three-Step methods.

Solutions Saved In Step-3 (Integer)

Column 30; Range 1 to 5. Only valid for Three-Step method.

Quickstart Flag (Integer)

| | | |
|-----------|---|--|
| Column 35 | 1 | Read previously saved data and perform quick optimization. |
| | 0 | Normal Optimization. |

In-depth Search

| | | |
|-----------|---|-----------------------------------|
| Column 40 | 0 | No. |
| | 1 | Yes (For Research Purposes only). |

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. (Only used if above flag is equal to 1)

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

Columns 16-20; Default value 1.0×10^{-3} .
 Columns 21-25; Default value 1.0×10^{-3} .
 Columns 26-30; Default value 1.0×10^{-3} .
 Columns 31-35; Default value 1.0×10^{-3} .
 Columns 36-40; Default value 5.0×10^{-4} .
 Columns 41-45; Default value 3.0×10^{-3} .
 Columns 46-50; Default value 1.0×10^{-3} .
 Columns 51-55; Default value 0.

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

EMISSION Card (Refer to the Edit section and Appendix B for detailed information)

This card identifies the beginning of the section for emissions factors data. Emissions factors are provided for: volatile organic compounds (VOC), carbon monoxide (CO), and oxides of nitrogen. This set of cards is optional. The following information is provided on Emissions card:

County Name (optional)

Columns 11-26

Year (optional)

Columns 27:30

Name of file containing the table used in this data file. (Optional)

Columns 31-42; A valid DOS file name.

REFERENCE

VOC Card

This card is used to provide emissions rates for volatile organic compounds. All data on this card is real with two decimal places.

- Columns 11-16; emissions, in grams per hour, for an idling vehicle.
- Columns 17-22; emissions, in grams per mile, for a vehicle traveling at 10 mph.
- Columns 23-28; emissions, in grams per mile, for a vehicle traveling at 15 mph.
- Columns 29-34; emissions, in grams per mile, for a vehicle traveling at 20 mph.
- Columns 35-40; emissions, in grams per mile, for a vehicle traveling at 25 mph.
- Columns 41-46; emissions, in grams per mile, for a vehicle traveling at 30 mph.
- Columns 47-52; emissions, in grams per mile, for a vehicle traveling at 35 mph.
- Columns 53-58; emissions, in grams per mile, for a vehicle traveling at 40 mph.
- Columns 59-64; emissions, in grams per mile, for a vehicle traveling at 45 mph.
- Columns 65-70; emissions, in grams per mile, for a vehicle traveling at 50 mph.
- Columns 71-76; emissions, in grams per mile, for a vehicle traveling at 55 mph.

CO Card

This card is used to provide emissions rates for carbon monoxide. The type and format of this data are the same as those on the VOC card.

NOX Card

This card is used to provide emissions rates for oxides of nitrogen. The type and format of this data are the same as those on the VOC card.

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

This card is mandatory and is used to supply the 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 for data

| | | |
|-----------|---|---|
| Column 45 | 0 | English (e.g., distance in feet and speed in miles per hour). |
| | 1 | Metric (e.g., distance in meters and speed in kilometers/hour). |

Measurement units for output

| | | |
|-----------|---|---|
| Column 47 | 0 | English (e.g., distance in feet and speed in miles per hour). |
| | 1 | Metric (e.g., 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)

NETWRK2 Card (Refer to: Edit/System Data screen section)

This optional card is used to provide data for the master signal. The master signal data is used to define the base reference point for printing offsets. The user can provide the following data:

Node identification number (Integer)

Columns 16-20. Default is the first signal on the first arterial entered.

Master Direction (northbound, southbound, eastbound, or westbound)

Column 25. Range: N, S, E, or W. Default: A-direction on the first artery at signal.

Base Offset (Integer)

Columns 28-30. Default value is zero (0). Value modulo cycle length is added to all offsets.

Phase reference point (beginning or ending of phase for referencing offsets)

Column 35. Range: B or E. Default is B (beginning of master approach through phase).

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

Columns 19-20. Range 2 to 20.

Time scale for time-space diagram

Columns 26-30. Default 3 seconds/character.

Distance scale for time-space diagram

Column 31-35. Default 67 feet/line or 20 meters/line, depending on data units.

REFERENCE

A-direction for this arterial

Column 56; Range N, S, E, or W (e.g., 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, common to most links, in A-direction of the 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, common to most links, in B-direction of the 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:

Node identification number (Integer)
Columns 16-20

A-direction of current or first artery at this signal
Column 25. Range N, S, E, or W. Must not conflict with the cross street A-Direction.
Default value is arterial A-direction read from the ARTERY card. In the previous version, fields 23-25 were used to enter sequence number of this signal on the current artery.

A-direction for cross street
Column 30. Range N, S, E, or W. Must not conflict with the above data.

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. Default: value given on the NETWORK card.

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.

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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)

The user can enter this data as seconds or as fractions of the cycle. If the entered number is larger than 1, it is assumed to be in seconds. As such, the program automatically converts the number to fractions of the cycle by using the lower cycle length value supplied by the user. This data ensures that minimum green times will be provided for the corresponding phase.

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. As such, 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 the user selects. This data overrides artery-wide values.

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

Southbound: Average 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 the user selects.

Northbound: Approach Link length; Columns 21-25.

Southbound: Approach Link Length; Columns 36-40.

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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. As such, 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. Figures 4 and 5 in the *Getting Started* section (pages 23 and 24) illustrate the four possible NEMA phasing sequences with overlap and the two cases of phasings without overlap.

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.

Overlap option for main street (Integer)

| | | | |
|-----------|-------|-----|--------------------------------------|
| Column 60 | Value | 0,1 | Phasing with overlap |
| | | 2 | Split phasing |
| | | 3 | Lead-lag or lag-lead without overlap |

Overlap option for cross street (Integer)

| | | | |
|-----------|-------|-----|--------------------------------------|
| Column 70 | Value | 0,1 | Phasing with overlap |
| | | 2 | Split phasing |
| | | 3 | Lead-lag or lag-lead without overlap |

RUN

The **Run** command saves the currently loaded data on the file *groupname.dat* and gives control to the optimization program (PASSR4). 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.

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 the user requests PASSR4 to save multiple solutions, a T7F file is generated for each solution saved. The T7F sub-menu, illustrated in Figure 29, can be used to run the program using any data file corresponding to the loaded *groupname*. The sub-menu provides the options described below.

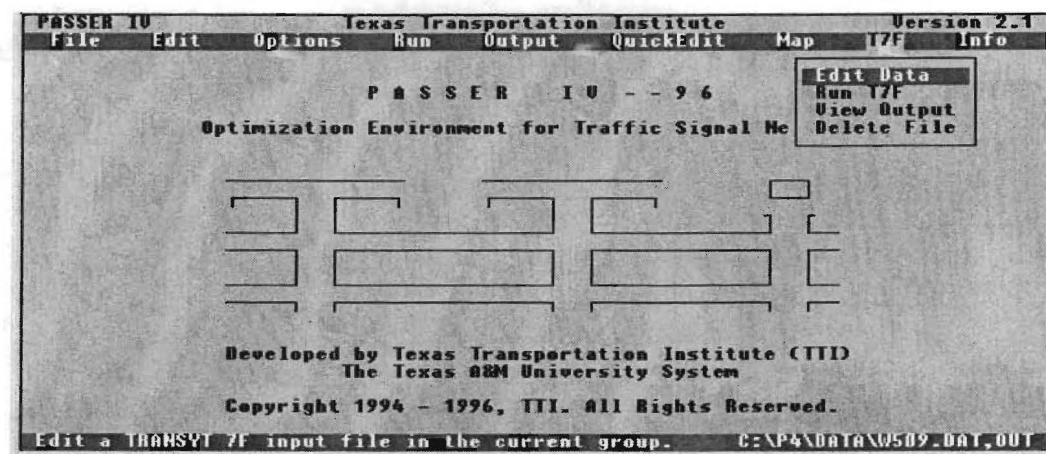


Figure 29: T7F sub-menu

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 30). The desired data file can be selected by using the arrow keys and 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 default values of T7F specific data.

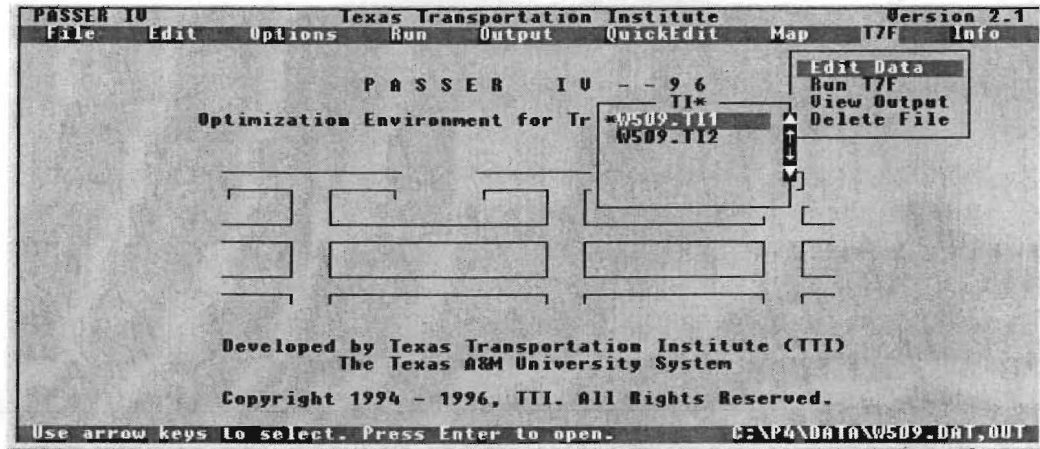


Figure 30: T7F Edit option showing available files to choose from

Run T7F

When the user selects this option, the program displays a list of all T7F input data files in the currently loaded group. The program launches T7F when an input file is selected by the user.

View Output

When the user selects this option, the program displays a list of T7F output files in the currently loaded group. The user then selects the output file he or she wants to view or print. Please refer to the Output section for detailed information about the usage of keys and functions.

Delete File

This option allows you to delete any specified T7F input or output file belonging to the currently loaded *groupname*. When you select this option, all T7F data and output files in the loaded group are displayed. Any one of these files can be selected for deletion. Before deleting a file, however, the program gives the user an option to continue the delete operation or to abort without deleting the selected file.

DESCRIPTION OF SPEED DATA

Desired link speeds and constraints on link speeds are specified using three types of speed data: average link speed, speed variation, 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 \pm speed variation. A speed variation of zero means that the link speed is fixed at the average link speed coded.

Example 1: If the average link speed and speed variation 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 variation. Example 2 illustrates the use of speed change.

Example 2: Suppose that average speed and speed variation 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 such a case:

Example 3: Let the average speed and variation 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 ($39-37=2$)

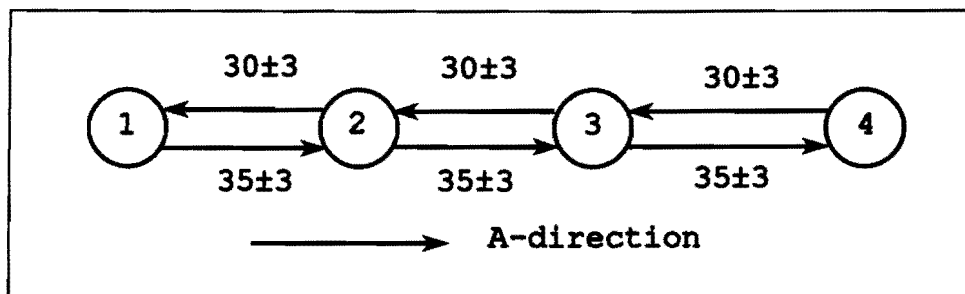
APPENDIX A: SPEED DATA AND RELATED CONCEPTS

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 variation 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 variation, those values are entered on the Signal Data screen. Examples 1 and 2 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:

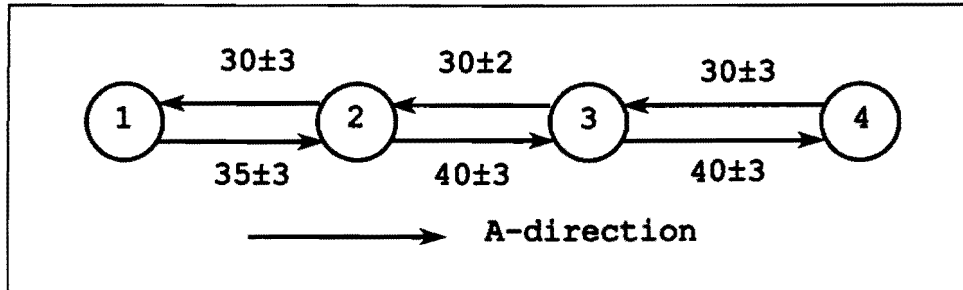


Note that all A-direction links have a speed range of 35 ± 3 and all B-Direction links have a speed range of 30 ± 3 . Therefore, this common data will be entered on the Artery Data screen as follows:

| | <u>A-Direction</u> | <u>B-Direction</u> |
|-----------------|--------------------|--------------------|
| Average Speed | 35 | 30 |
| Speed Variation | 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) than the next two links (40); whereas, the second link (from signal 3 to signal 2) in the B-Direction has a different speed range value from the other links in the same direction. 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:

| | <u>A-Direction</u> | <u>B-Direction</u> |
|-----------------|--------------------|--------------------|
| Average Speed | 40 | 30 |
| Speed Variation | 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 approach data:

| | <u>NB</u> | <u>SB</u> | <u>EB</u> | <u>WB</u> |
|------------|-----------|-----------|-----------|-----------|
| 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 the 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. Furthermore, optimal average travel time is a function of the speed on that link. Thus, the optimum offset for a link is selected from a variation of speeds defined by the user supplied data.

The larger the variation 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 variation of speeds given for all links be as small as possible.

INTRODUCTION

A number of factors/variables affect the consumption of fuel and the emission of pollutants by vehicles traveling within a signalized urban roadway system. These include: vehicle characteristics (type and size of vehicle fleet), atmospheric conditions (ambient temperature), pavement type and conditions (rough, smooth, wet, dry, icy, etc), and traffic flow conditions (quality of signal control, delay, level of service, etc.). The absolute determination of these measures-of-effectiveness (MOE's) cannot be performed in PASSER IV since all of the data is not available to the program. Further, the absolute accuracy of fuel consumption and emissions estimation, although important, is not necessary for relative comparisons between existing and proposed signal control strategies and for the comparison of alternate signal timing strategies for a given control period during a specific day of the week. Rather, the use of simple procedures, based on the quality of traffic flow (travel time on a link, delay, and stops), are sufficient for two reasons:

1. For a specific metropolitan area or county, vehicle characteristics and physical pavement type experience slow change over a long period of time and can be assumed constant for day-to-day operational analysis.
2. Since a specific signal control period is much shorter (less than a day) than a given season (summer, winter, etc.), the effects of ambient temperatures on the operating characteristics of vehicle engines can also be assumed constant among various signal timing plans for a control period.

Therefore, PASSER IV utilizes models that take into account the effects of traffic conditions on fuel consumption and emissions of vehicles traveling on signalized urban arterials. These procedures are described in the following sections.

FUEL CONSUMPTION ESTIMATION

Fuel consumed by vehicles traveling on an arterial link between two intersections can be attributed to three factors related to the traffic conditions and signal coordination: fuel consumed while traveling from the upstream signal to the downstream signal, fuel consumed while stopped at an intersection, and fuel consumed while decelerating to a stop and accelerating back to a desired speed. PASSER IV uses the fuel consumption model described below. The material presented in this section had been adapted from: Fambro et al., *Implementation Guidelines for Retiming Isolated Intersections*, Research Report No. FHWA/TX-93/1164-1, College Station, Texas, December 1992.

$$F = \begin{aligned} & (A_{11} + A_{12} * V + A_{13} * V^2) * TT \\ & + (A_{21} + A_{22} * V + A_{23} * V^2) * D \\ & + (A_{31} + A_{32} * V + A_{33} * V^2) * S \end{aligned}$$

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where:

| | | |
|-----------------|---|---|
| F | = | estimated total system fuel consumption, in gallons per hour; |
| TT | = | total travel, in vehicle miles per hour; |
| D | = | total delay, in vehicle-hours per hour; |
| S | = | total stops, in stops per hour; |
| V | = | cruise speed, in miles per hour; and |
| A _{ij} | = | regression model beta coefficients, and is given by: |

$$A_{ij} = \begin{vmatrix} 0.075283 & -1.5892E-3 & 1.50655E-5 \\ 0.73239 & 0.0 & 0.0 \\ 0.0 & 0.0 & 6.14112E-6 \end{vmatrix}$$

In order to apply the above model, estimates of total travel, vehicular delay, and total stops are needed. Furthermore, the estimation of total stops requires the estimation of queue lengths at signalized approaches. In the following subsections, we describe procedures for the calculation of these quantities. It should be noted that these measures-of-effectiveness are estimated for each movement at an approach to the traffic signal.

Total Travel

Total travel for the *i*th traffic movement on the link from signal *k* to signal *j* (TT_{ikj}), in vehicle-kilometers (or vehicle-miles) per hour, is obtained using the following relationship:

$$TT_{ikj} = Vol_{ij} \times LL_{kj}$$

Where,

| | | |
|-------------------|---|---|
| Vol _{ij} | = | traffic volume, vehicles per hour, for the <i>i</i> th movement at signal <i>j</i> , and, |
| LL _{kj} | = | length of link, in kilometers (or miles) from signal <i>k</i> to signal <i>j</i> . Note that each direction of a link between two signals is considered separately. |

Total Approach Delay

In PASSER IV, the total delay for through movements is calculated using a methodology that accounts for traffic progression. The delay for non-progressed approaches (all movements at external links and left-turn movements) is calculated using the *Highway Capacity Manual* method.

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The HCM equation for calculating stopped delay consists of two parts: delay due to uniform arrivals (d_1) and delay due to random and overflow arrivals (d_2). These are described as follows:

$$d_1 = \frac{0.38C[1 - (g/C)]^2}{[1 - (g/C)(\text{Min}(X,1.0))]}$$

where:

- d_1 = uniform delay in seconds per vehicle;
- C = cycle length in seconds;
- g = green time per phase in seconds;
- $\text{Min}(X,1)$ = the lesser value of either X (v/c ratio for lane group) or 1.0; and
- X = volume to capacity ratio for that phase.

$$d_2 = 173X^2 [(X - 1) + \sqrt{[(X - 1)^2 + mX/c]}]$$

where:

- d_2 = incremental delay in seconds per vehicle;
- X = volume to capacity ratio for that phase;
- m = a calibration factor for incorporating the effects of arrival type and degree of platooning; and
- c = capacity of lane group, in vehicles per hour.

The intersection stopped delay is as follows:

$$d = d_1 + d_2$$

Total delay can be obtained from the stopped delay using the following relationship:

$$D = 1.3 * d$$

where:

- D = total delay, in seconds per vehicle; and
- d = stopped delay, in seconds per vehicle.

Total Stops

Total stops for a specific movement at a signal approach is a product of the total demand volume for that approach and the stop rate. Stop rate is the average number of stops per vehicle and is calculated as follows:

$$h = 0.9 \left(\frac{1 - u}{1 - y} + \frac{N_o}{qC} \right)$$

where:

- h = average number of complete stops per vehicle (stop rate);
- u = green time ratio (g/c);
- y = flow ratio (q/s);
- q = flow in vehicles per second;
- C = cycle length in seconds; and
- N_o = average overflow queue in vehicles.

Average Overflow Queue Length

The average number of vehicles in the queue at the start of the green period is calculated as follows:

$$N = qr + N_o$$

where:

- N = average number of vehicles in queue, in vehicles;
- q = arrival flow rate in vehicles per second, in vehicles per second;
- r = effective red time in seconds, in seconds; and
- N_o = average overflow queue in vehicles and given by:

$$N_o = \frac{QT_f}{4} \left(z + \sqrt{z^2 + \frac{12(x-x_o)}{QT_f}} \right)$$

where:

- Q = capacity in vehicles per hour;
- T_f = flow period, in hours;
- z = (x - 1);
- x = degree of saturation (q/Q); and
- x_o = (0.67 + sg/600), where s = saturation flow, in vehicles per second, and g = effective green time for the lane group, in seconds.

The above equation for queue length is based on a theoretical model, which assumes that vehicles join the queue when they reach the stop-line. Since vehicles actually join the queues before reaching the stop-line, this equation underestimates the maximum queue length. Maximum queue length can be calculated as follows:

$$N_m = \frac{qr}{1 - y} + N_o$$

where:

- N_m = maximum length of the queue; and
- q = arrival flow rate in vehicles per second;
- r = effective red time in seconds; and
- y = flow ratio (volume/saturation flow rate).

ESTIMATION OF VEHICULAR EMISSIONS

The Clean Air Acts Amendments of 1990 established stricter Federal standards for urban air quality. In addition, these amendments requires the Environmental Protection Agency (EPA) to work in cooperation with State Transportation Departments (DOTs) and Metropolitan Planning Organizations (MPOs) to determine conformity to these standards and to impose sanctions when Federal standards are not achieved by the established date. The DOTs and MPOs have the sole responsibility for implementing transportation control measures (TCM) that are consistent with the most recent mobile source emissions and provide for quick implementation. The EPA requires transportation agencies to use the MOBILE model for determining mobile emission rates. MOBILE is developed by the EPA and is updated every three years.

Estimates of three types of vehicular emissions, volatile organic compounds (VOC), carbon monoxide (CO), and oxides of nitrogen (NOx), are needed to determine the impacts of urban vehicular travel on the air quality. VOCs are hydrocarbons emissions from vehicles as measured by the flame ionization detector (FID) used in testing, plus a correction for Aldehydes emitted but not picked up by FID. VOC and NOx are major elements contributing to the formation of fog. CO is a colorless gas produced by incomplete burning of carbon in fuels. It is poisonous and harmful to humans.

The current TxDOT practice is to use the MOBILE model to obtain estimated emissions factors, corresponding to various traffic conditions, for each Texas County. These include emissions rates (in grams per hour) for idling vehicles and emissions rates (in grams per mile) for various running speeds. Table A-1 provides an illustration. The total emissions resulting from a specific signal timing plan are then calculated using travel speeds, stopped delay, and stops associated with that signal timing plan. We adopted this methodology for vehicular emissions estimation in PASSER IV. In addition to meeting the EPA requirement regarding the use of the MOBILE model, this will allow PASSER IV to remain robust for future enhancements. The equations used in PASSER IV for the calculation of vehicle emissions are given below.

$$CO_{total} = Delay_{Stopped} \times CO_{idle} + VMT \times HC_{speed}$$

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$$VOC_{total} = Delay_{Stopped} \times VOC_{idle} + VMT \times VOC_{speed}$$

$$NOx_{total} = Delay_{Stopped} \times NOx_{idle} + VMT \times Nox_{speed}$$

Where:

| | | |
|-------------------|---|---|
| VOC_{total} | = | Total VOC emissions (grams/hour), |
| VOC_{idle} | = | VOC emissions (grams/hour), for an idling vehicles, |
| VOC_{speed} | = | VOC emissions (grams/mile), for a given speed, |
| NOx_{total} | = | Total NOx emissions (grams/hour), |
| NOx_{idle} | = | NOx emissions (grams/hour), for an idling vehicles, |
| NOx_{speed} | = | NOx emissions (grams/mile), for given speed, |
| CO_{total} | = | Total CO emissions (grams/hour), |
| CO_{idle} | = | VOC emissions (grams/hour), for an idling vehicles |
| CO_{speed} | = | VOC emissions (grams/mile), for a given speed, |
| $Delay_{stopped}$ | = | Stopped delay for a traffic movement (hrs), and |
| VMT | = | Vehicle-miles-travel per hour. |

When optimal speed for a link does not exactly match the supplied speeds in the emissions table, interpolation is used to obtain the values of emissions factors.

APPENDIX B: FUEL CONSUMPTION AND EMISSIONS ESTIMATION

| Table A-1 MOBILE 5.0 EMISSIONS (g/mi) ATTAINMENT COUNTY 1994 | | | |
|---|------------|-----------|------------|
| SPEED mph | VOC | CO | NOx |
| 0 | 52.14 | 446.24 | 5.47 |
| 10 | 6.48 | 75.08 | 3.60 |
| 15 | 4.69 | 53.36 | 3.35 |
| 20 | 3.78 | 42.37 | 3.22 |
| 25 | 3.13 | 35.03 | 3.22 |
| 30 | 2.69 | 30.05 | 3.23 |
| 35 | 2.38 | 26.54 | 3.27 |
| 40 | 2.15 | 24.03 | 3.33 |
| 45 | 1.98 | 22.27 | 3.42 |
| 50 | 1.89 | 21.51 | 3.72 |
| 55 | 1.88 | 21.69 | 4.34 |
| 60 | 2.39 | 38.27 | 5.02 |
| 65 | 2.90 | 55.08 | 5.79 |

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