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| 16. Abstract<br>PASSER IV is a program for timing traffic signals in networks based on progression bandwidth optimization. It is capable of optimizing signal timings for arterials as well as multi-arterial closed-loop networks. PASSER IV is the only practical bandwidth-based signal timing optimization for multi-arterial closed-loop networks. This manual is a step-by-step training guide for teaching the use of PASSER IV for timing traffic signals. A computer diskette containing data sets for use in future training courses accompanies this manual. The material presented in this manual was prepared to teach a two-day pilot training course to a selected group of TxDOT employees and contains suggestions provided by the course participants. The pilot course was taught at TxDOT facilities in Austin, Texas. Based on the success of the pilot course, the researchers recommend that this course be taught to a wider audience of TxDOT employees as well as other engineers whose job function requires timing of traffic signals in their respective jurisdictions. |   |  |           |
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**PASSER IV-96**  
**VERSION 2.1**  
**TRAINING MANUAL**

by

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## **IMPLEMENTATION STATEMENT**

This project enhanced and further developed PASSER IV, a program for optimizing bandwidth-based signal timings in signalized arterial networks. Researchers provided a copy of the program and its user's manual to TxDOT in early 1997. Several TxDOT districts are currently using the program to time traffic signals in their respective jurisdictions. Further, in the July of 1997, the research supervisor taught a PASSER IV pilot training course at TxDOT facilities in Austin, Texas. A selected group of employees from several TxDOT districts attended this two-day pilot training course. The objective of the training course was to teach the effective use of PASSER IV for timing traffic signals. This manual contains the teaching material used in that pilot training course and includes the comments provided to the research team by the course participants. A computer diskette containing data sets used in the pilot training course also accompanies this manual. As part of the training course preparation, the research team also optimized signal timings for the City of Nacogdoches, Texas. Researchers also included the Nacogdoches signal timing problems in the pilot training. This manual will be useful in future training courses. In addition, sufficient detail is provided in the training material to allow for its easy use as a self-study guide for more experienced users.



## **DISCLAIMER**

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT), or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The Engineer in charge of the project was Nadeem A. Chaudhary, P.E. # 66470.

Progression Analysis and Signal System 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 any related documentation are copyrighted. The users are advised to use the program and related documentation at their own risk. TTI, TxDOT, and FHWA are not liable for any damages (direct or indirect) resulting from the use of PASSER IV or related documentation.

## **ACKNOWLEDGMENT**

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Special thanks go to Mr. John Black, City of Richardson, Texas, for his support. Mr. Black provided useful comments, the incorporation of which, greatly enhanced the training material.

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## SUMMARY

PASSER IV is a program for optimizing signal timings in multi-arterial traffic signal networks. It is the only practical bandwidth-based signal timing program for networks available to the traffic engineering community. Since PASSER IV is a relatively new software package, there is a need to hold training courses to teach its effective use. TxDOT identified this need and expanded the original scope of SPR project 0-1477 to allow the development of necessary training material and to conduct a pilot training course. Researchers prepared a draft PASSER IV training manual, and taught a two-day pilot training course at TxDOT facilities in Austin, Texas. A small (one dozen) group of TxDOT employees from various districts attended this training course. The final training manual is enhanced by incorporating comments received from the course participants, during and after the pilot training course. In the addition, detailed guidelines have been added to enable its use as a self-study guide.

This report contains the final training manual. It consists of five sections. These sections are organized as follows:

- Section 1: Review of bandwidth optimization concepts as they relate to PASSER IV.
- Section 2: Hands-on instructions on how to code data and the use of PASSER IV to time signalized arterials.
- Section 3: Hands-on instructions on how to code data for a network. This section also illustrates how to handle unusual intersections.
- Section 4: Discussion of advanced concepts and additional PASSER IV features.
- Section 5: Timing of signals for a real network from Nacogdoches, Texas.

The objective of the last section was to reinforce the material presented in previous sessions. Researchers used recent data from the City of Nacogdoches for this purpose. The resulting optimal signal timings for the City of Nacogdoches were given to TxDOT for implementation.

# **INTRODUCTION AND BASIC CONCEPTS**

## **INTRODUCTION**

The primary function of a traffic signal is to provide safe and equitable service to competing traffic movements at a roadway intersection. When two or more signalized intersections are located in close proximity, their operation must be coordinated. The objective of coordination is to provide smooth flow to platoons of traffic released from one intersection and traveling to the adjacent intersection. Coordination of traffic signals requires the determination of optimal values of several signal timing parameters. These parameters include: a common cycle length, green splits, signal phasing sequences, and offsets.

A number of computerized tools (computer models) are available to aid the traffic engineering community in the analysis and coordination of traffic signals. These tools can be classified into two major categories: simulation, and optimization. They can be further classified as either macroscopic or microscopic models. Macroscopic models base their analysis on the average behavior of a group of vehicles. Microscopic models, on the other hand, are more detailed in that they analyze the behavior of each individual vehicle in the system.

### **Traffic Simulation Models**

Models in this category provide abilities to assess a given scenario. Simulation models require the complete specification of a traffic scenario including traffic control/coordination strategy as well as the specific set of traffic conditions. These models do not have the ability to automatically select the best strategy from among all possibilities. Nevertheless, simulation models are useful tools for analyzing existing traffic scenarios and alternate strategies without having to experiment with the real system. TRAF-NETSIM belongs to this category of traffic models.

### **Signal Timing Optimization Models**

Signal timing optimization models have the ability to select the best values of signal timing parameters for the given traffic conditions. Models in this category can be further classified as either delay-based or bandwidth-based. Delay based models select signal timings to minimize total system delay to vehicles, whereas, bandwidth based programs give higher priority to through vehicles by maximizing progression bandwidth. Among the most commonly used models, TRANSYT-7F and Synchro are delay-based models, whereas, PASSER II and PASSER IV are bandwidth-based models. Progression Analysis and Signal System Evaluation Routine (PASSER<sup>TM</sup>) is a family of signal timing optimization programs originally developed by the Texas Transportation Institute (TTI) for the Texas Department of Transportation (TxDOT).



## Summary and Organization of this Manual

Table 1-1 provides a comparison of the most commonly used traffic models. The information provided in the table includes: model classification, types of traffic facilities that each model applies to, signal timing parameters calculated (C) or optimized (O) by each programs, and the measures-of-effectiveness reported by each model.

**Table 1-1: A comparison between commonly used optimization traffic models.**

|   | PASSER II | PASSER III | PASSER IV | TRANSYT-7F | SYNCHRO |
|---|-----------|------------|-----------|------------|---------|
| <b>Model Classification</b>                 |           |            |           |            |         |
| <i>Delay</i>                                | ✓         | ★          |           | ★          | ★       |
| <i>Bandwidth</i>                            | ★         | ★          | ★         | ✓          |         |
| <b>Model Applications</b>                   |           |            |           |            |         |
| <i>Interchanges</i>                         | ✓         | ★          |           |            |         |
| <i>Arterials</i>                            | ★         |            | ★         | ★          | ★       |
| <i>Networks</i>                             |           |            | ★         | ★          | ★       |
| <b>Parameters Optimized</b>                 |           |            |           |            |         |
| <i>Cycle</i>                                | ★         | ★          | ★         | ★          | ★       |
| <i>Splits</i>                               | ★         | ✓          | ✓         | ★          | ★       |
| <i>Offsets</i>                              | ★         | ★          | ★         | ★          | ★       |
| <i>Phasing</i>                              | ★         | ★          | ★         |            | ★       |
| <b>MOEs Reported</b>                        |           |            |           |            |         |
| <i>Delay</i>                                | ★         | ★          | ★         | ★          | ★       |
| <i>Stops</i>                                |           |            | ★         | ★          | ★       |
| <i>Queue Length</i>                         |           |            | ★         | ★          | ★       |
| <i>Fuel Consumption</i>                     | ★         |            | ★         | ★          |         |
| <i>Emissions</i>                            |           |            | ★         |            |         |
| <i>V/C Ratios</i>                           | ★         | ★          | ★         | ★          |         |
| ✓ Limited Capability      ★ Full Capability |           |            |           |            |         |

The following subsections describes PASSER IV and discuss concepts related to progression bandwidth optimization as they apply to PASSER IV. The remainder of this training manual describes how to use PASSER IV to time traffic signals.

## **PASSER IV BACKGROUND**

PASSER IV, first released in 1984, is the latest addition to the PASSER series of software packages. It is a progression bandwidth-based signal timing optimization program for arterials and multi-arterial (open and closed) networks. The latest version of PASSER IV available for public distribution is PASSER IV-96, Version 2.1.

Much of the input data required by PASSER IV is similar to that of other computerized traffic signal timing programs. Thus, most new users are already familiar with the program's input data needs. Users' familiarity with the input data along with a well designed user interface allows even the novice user to successfully code and optimize a signal timing problem within a few hours.

PASSER IV uses an advanced mathematical programming technique to solve network signal timing optimization problems. The user does not need to know how the mathematical programming works. However, familiarity with a few basic concepts is beneficial and can lead to a better utilization of the software. These concepts will be discussed in a later section.

PASSER IV produces almost all of the signal timing information needed for plan development and field implementation. In addition, it calculates and reports an array of measures-of-effectiveness (MOEs) for use in determining the quality of the timing plans generated.

PASSER IV consists of two modules: the core optimization routine (PASSR4), and the user interface. PASSR4 is a complete signal timing optimization package that can be executed from a command line. When executed, PASSR4 reads data from a specified input file, checks data for errors, performs calculations, and prints its output report in a specified output file. The user interface provides several functions for easy use of PASSR4. These include abilities to:

- Create, modify, and view the input data files for PASSR4,
- Execute PASSR4, and
- View and/or print the PASSR4 output.

## **Program Features**

As shown in Figure 1-1, PASSER IV can handle any combination of one-way or two-way arterials. It determines the values of signal timing parameters that simultaneously maximize progression bandwidth efficiency on all directions along the arterial in the defined network. One of its main features is the ability to optimize phasing sequences in multi-arterial networks. The following is a list of other key features of PASSER IV:

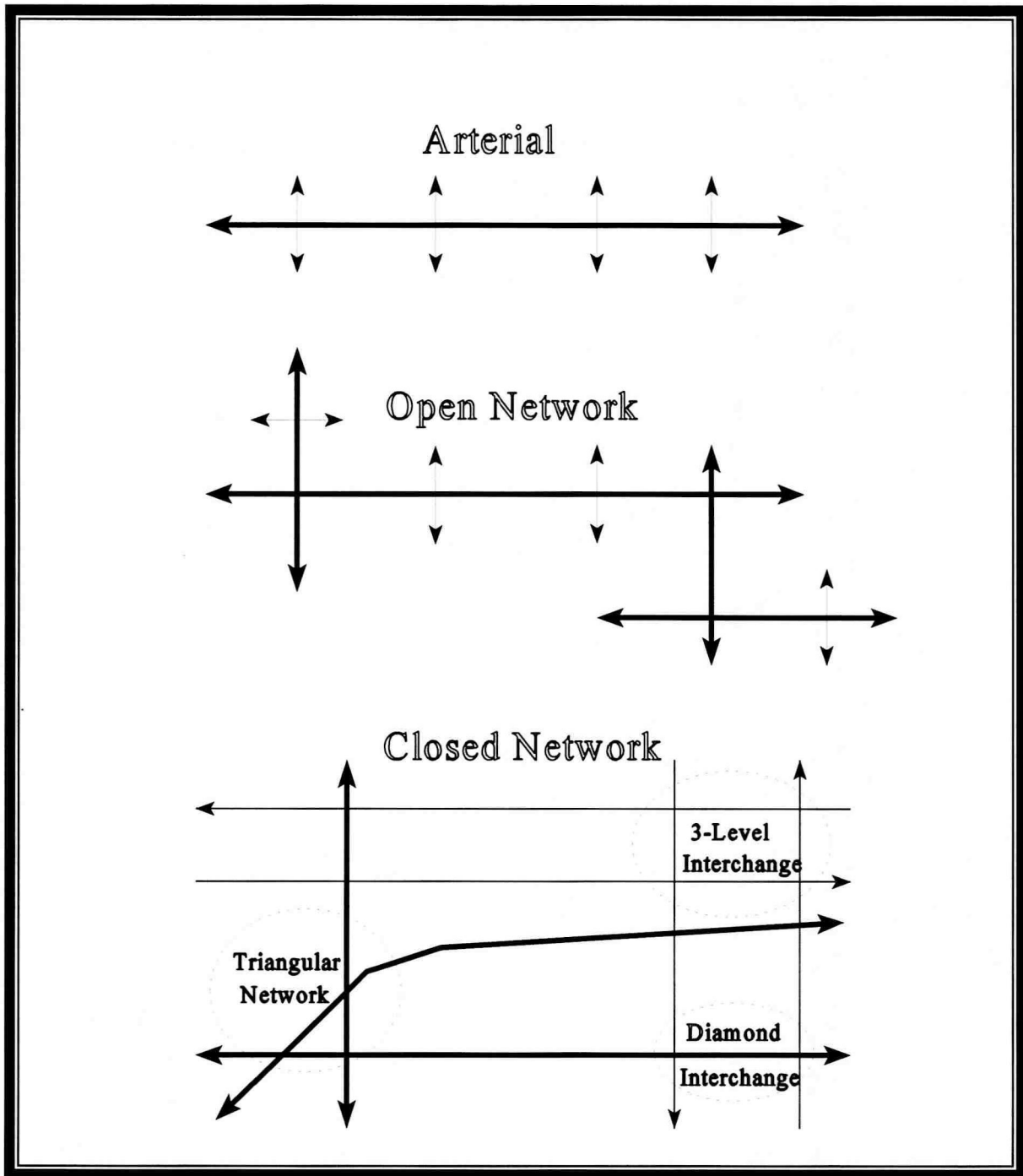
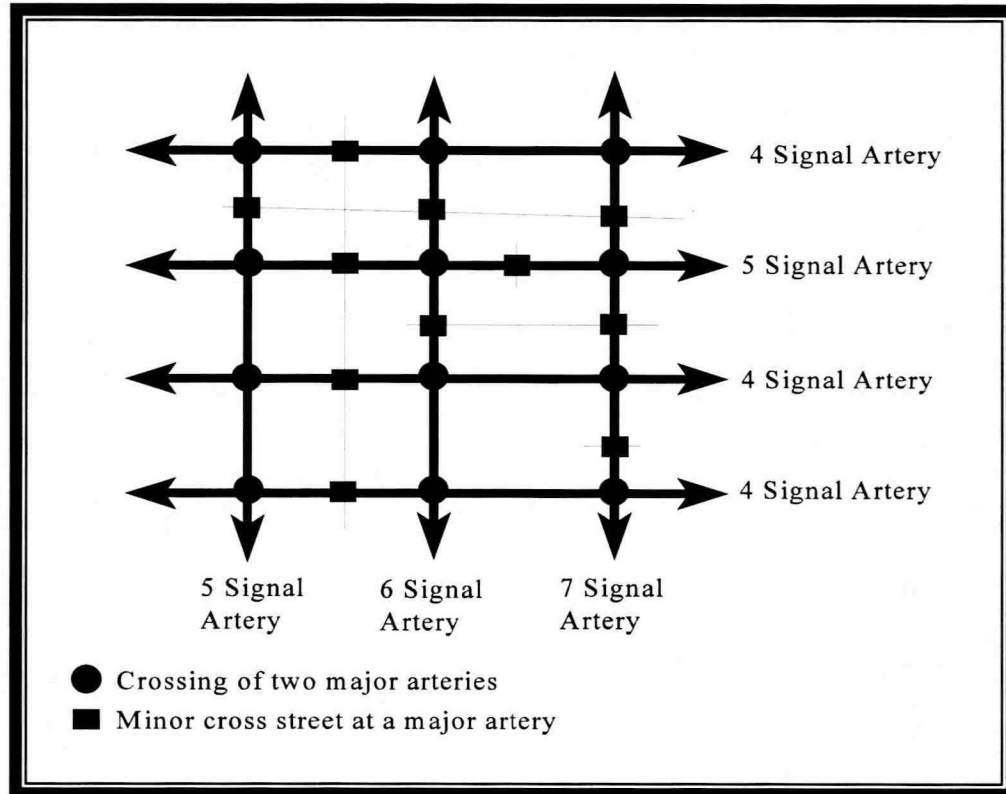


Figure 1-1: Potential Applications of PASSER IV.

- Allows up to 50 signals and 20 arterials in the network. An artery can have between 2 and 20 signals. Figure 1-2 illustrates the relationship between signals in the network to signals on the arterials in the network.
- Allows cycle length minimization.
- Allows a user to select the master signal for referencing offset.
- Allows specification of different measurement units for input data and output report.
- Can print multiple signal timing solutions.



**Figure 1-2: A 23 Signal Multi-Arterial Network.**

## **PASSER IV OPTIMIZATION PROCESS AND QUALITY OF SOLUTIONS**

PASSER IV maximizes progression bandwidth efficiency by determining the values of four signal timing parameters, namely: green splits, systemwide cycle length, left-turn phasing sequences, and offsets between signals. First, the program uses Webster's method to calculate the green splits. Then, it determines the remaining parameters through its optimization process. The optimization process examines all possible sets of these parameters and selects the best set.

## Progression Bandwidth versus Efficiency

Progression bandwidth for an arterial direction is the length of the time window during which vehicles can travel from the first signal to the last signal without stopping. It is measured in seconds. Figure 1-3 illustrates the time-space diagram for a three intersection arterial running north-south. This time-space diagram is drawn using the PASSER IV format. In this format, the Y-axis represents the distance between signals (meters or feet) and the X-axis (from left to right) represents the elapsed time. In addition, traffic flow along the A-direction is always displayed from top to bottom. For the case shown in Figure 1-3, northbound was selected as the arterial A-direction. Thus, the bands on the left- and right-sides are the A- and B-direction bands, respectively. Labels A and B identify these bands. The slopes (distance traveled per unit time) of the bands are the average flow speeds in the respective directions. Further, link distances are displayed on the rightmost side. These distances are measured from the first signal in the A-direction. In this example, the second (third) signal is 304 (762) meters away from the first signal. The distance for the first signal is always zero. The program uses the following symbols to print the phasing sequence and split information for each signal:

- NNNN Green phase for northbound approach only,
- SSSS Green phase for southbound approach only,
- EEEEE Green phase for eastbound approach only,
- WWW Green phase for westbound approach only,
- Blanks Green for both A and B-direction through movements,
- ===== Red phase for all movements on this artery. Cross street traffic gets green during this time period.

The time-scale (seconds/character) determines the length of time represented by each character and as a result, the phase lengths. In this example, all signals have the same phasing sequence for the artery. This phasing is illustrated at the top part of the figure. These phasing sequences were deliberately selected. The result was a lower total band than what was possible. In the next section, we will illustrate how phasing sequence optimization (letting PASSER IV choose different phasing sequences) can improve the progression bandwidth. This is one of the main strengths of PASSER IV over many other signal timing optimization packages for networks.

It should be pointed out that bandwidth maximization forces the selection of the longest possible cycle length. An alternate approach is to maximize progression efficiency. Progression efficiency, in fractions of the cycle length, results when the progression bandwidth is divided by the cycle length. It is a unitless quantity. Maximizing progression efficiency is equivalent to maximizing bandwidth, however; it does not force the cycle length to reach the upper limit. The example provided in Table 1-2 illustrates this difference by using two solutions for a hypothetical signal timing problem. It is assumed that all cycle lengths in the specified range provide sufficient capacity. The reader will note that the second timing-plan with a smaller cycle length is better than the first timing plan since it resulted in higher bandwidth efficiency, although it had a lower bandwidth. For this reason, PASSER IV maximizes progression efficiency.

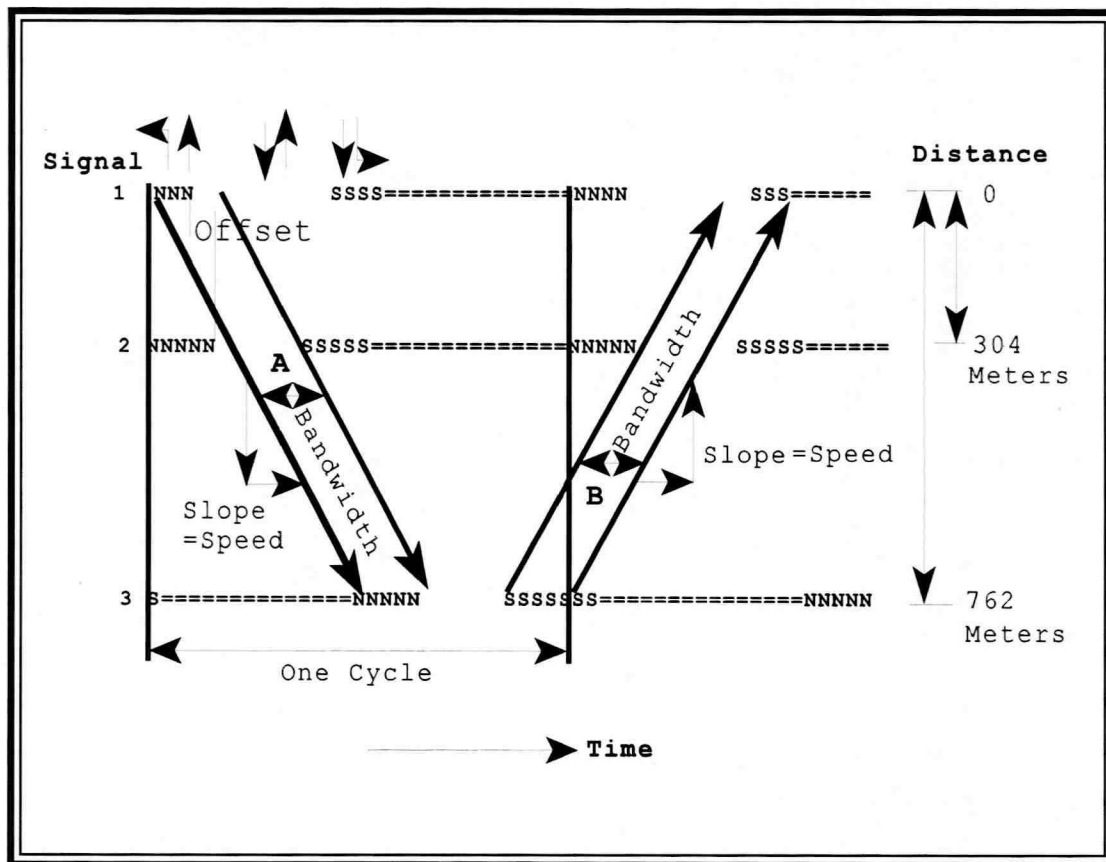


Figure 1-3: Time-Space Diagram for a Three-Intersection Arterial.

Table 1-2. Bandwidth vs. Efficiency.

| Timing Plan | Cycle length in Seconds | Bandwidth in Seconds | Efficiency in Fraction (Percent) |
|-------------|-------------------------|----------------------|----------------------------------|
| 1           | 100                     | 30                   | 0.3 (30%)                        |
| 2           | 80                      | 26                   | 0.325 (32.5%)                    |

## Quality of PASSER IV Solutions

For each arterial in the network, PASSER IV prints two numbers, namely: efficiency and attainability. These numbers can be used to evaluate the quality of a signal timing plan (solution) and to compare it with other solutions. The following subsections provide guidelines for interpreting these numbers.

### *Progression Efficiency*

As described above, efficiency is the percentage (or fraction) of cycle length used for the progression of through traffic. The formula used for calculating efficiency is as follows:

$$E = \frac{B_A + B_B}{2 \times C} \times 100$$

Where:

E is the arterial efficiency in percent,

B<sub>A</sub> and B<sub>B</sub> are A and B-direction progression bands in seconds, respectively, and

C is the system cycle length in seconds.

Table 1-3 provides guidelines for using efficiency to determine the quality of progression. In general, solutions with efficiency of less than 25% are undesirable.

**Table 1-3: Efficiency vs. Quality of Progression.**

| Efficiency Range | Quality of Progression |
|------------------|------------------------|
| 37% or higher    | Excellent              |
| 25% to 36%       | Good                   |
| 13% to 24%       | Fair                   |
| 0% to 12%        | Bad                    |

### *Attainability*

By definition, progression band for an arterial direction cannot be larger than the smallest through green in that direction. Attainability is the percentage of the smallest through green used for the progression band. The formula for calculating attainability is as follows:

$$A = \frac{B_A + B_B}{G_A + G_B} \times 100$$

Where:

A is the attainability in percent,

$B_A$  and  $B_B$  are A-direction and B-direction progression bands in seconds, respectively, and,

$G_A$  and  $G_B$  are the smallest through green times in A and B-directions, respectively.

Table 1-4 provides guidelines for using attainability to determine the quality of progression. Attainability values of 69% or lower are undesirable and suggest the need for changes in signal timings. These changes may be minor or major. Minor changes in signal timings may be as simple as use of alternate splits and/or phasing sequences. Major changes, on the other hand, include: implementation of one-way progression, dividing the arterial or network into multiple coordinated systems, and if everything else fails, geometric changes. Redesigning the signal approaches to remove split phasing requirement is an example of geometric changes.

**Table 1-4: Attainability vs. Quality of Progression.**

| Attainability Range | Quality of Progression |
|---------------------|------------------------|
| 99% to 100%         | Excellent              |
| 90% to 98%          | Good                   |
| 70% to 89%          | Fair                   |
| 0% to 69%           | Bad                    |

## **Determination of Signal Timing Parameters**

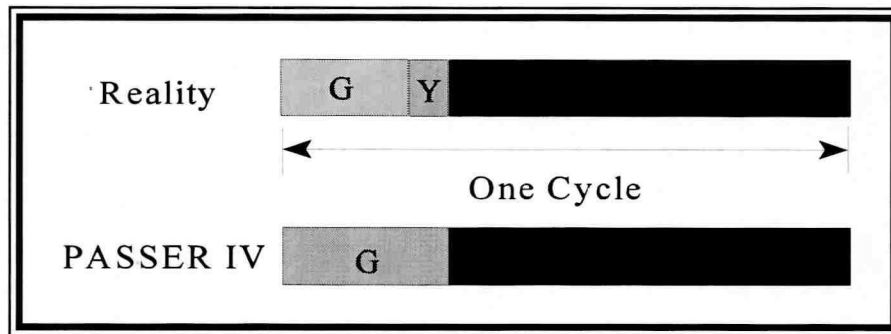
### ***Systemwide Cycle Length***

From the user specified cycle length range (lower and upper limit), PASSER IV selects the best cycle length. It assumes that all cycle lengths in the specified range provide sufficient capacity to handle the specified traffic demand. The user can fix (simulate) the cycle length by selecting the same value for the lower and upper cycle length limits.



### ***Green splits***

PASSER IV only considers through and protected left-turn movements in its calculation of green splits. For a shared lane, it adds the right-turn demand to the through demand. Further, it ignores the demand for an exclusive right-turn lane. For each movement or phase at a signal, PASSER IV allocates two time periods in a signal cycle. These periods are referred to as green and red splits. Green split for a movement is the fraction of the signal cycle during which the signal indication is green for that movement. Red split for a movement is the fraction of the signal cycle during which signal indication is red for that movement. In addition, this is the time during which signal displays green to those traffic movements that conflict with the movement under consideration. When using PASSER IV, green splits for all movement at a signal are either supplied by the user or calculated using volume and saturation-flow data. The program calculates the red split for each movement by subtracting the corresponding green split from 1. Further, it assumes that any yellow and red clearance times for a movement are included in its green split. Figure 1-4 illustrates this.



**Figure 1-4: Green and Red Periods for a Movement.**

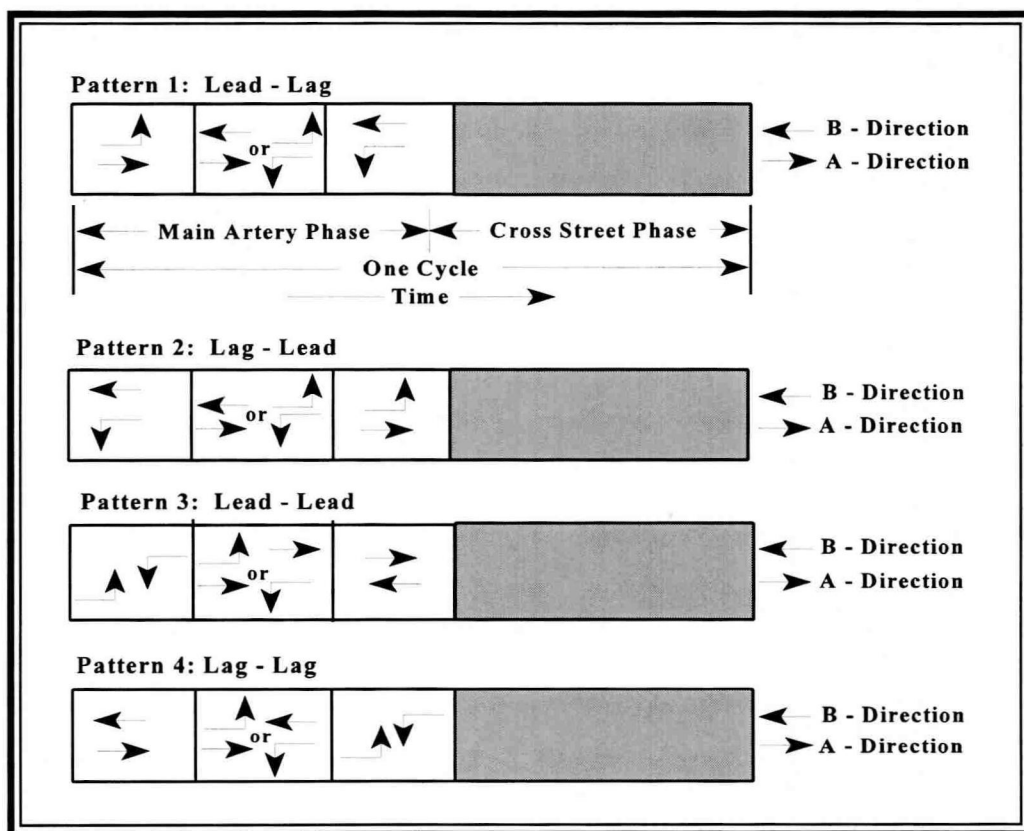
When the user does not provide green splits, they are calculated by the program using traffic volumes, saturation flow rates, lost time, and the lower cycle length entered by the user. PASSER IV uses Webster's method to calculate splits. This ensures equity between all traffic movements. PASSER IV calculates the green split using the steps given below:

1. Calculates volume to saturation flow (V/S) ratios for all movements,
2. Determines critical movements by adding the V/S ratios for conflicting phases,
3. Determines total lost time based on the number of phases,
4. Calculates effective green splits for critical movements using the relationship:  
$$\text{Sum of V/S ratios for critical movement pairs} = \text{Lower cycle length} - \text{Total Lost Time},$$

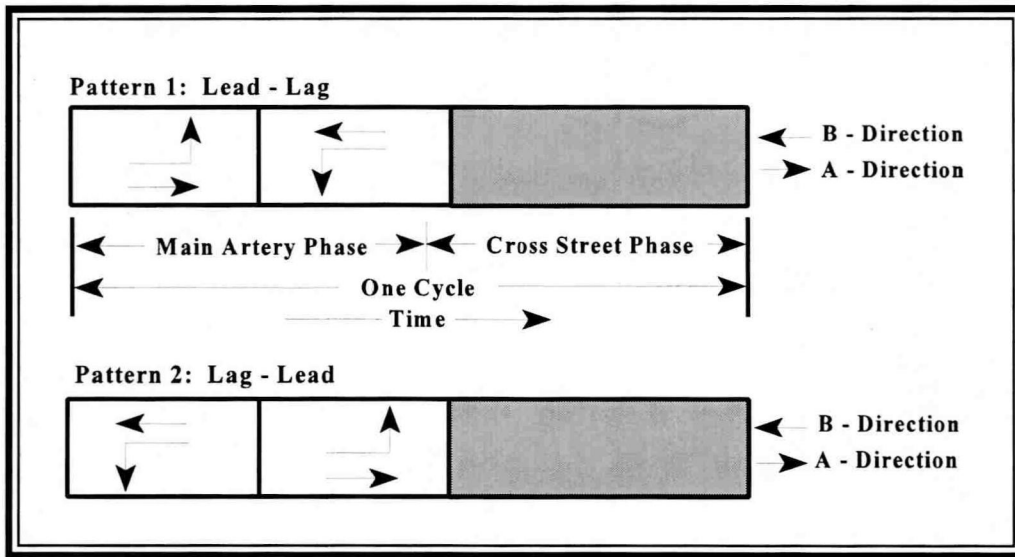
5. Adds movement lost times to the effective splits to obtain total green splits (G),
6. Determines splits for non-critical movements by matching them to the critical movements,
7. Adjusts all splits to account for any specified minimum green requirements,
8. Finally, converts all splits to fractions of the cycle length by using the lower cycle length.

### ***Left-turn Phasing Sequences***

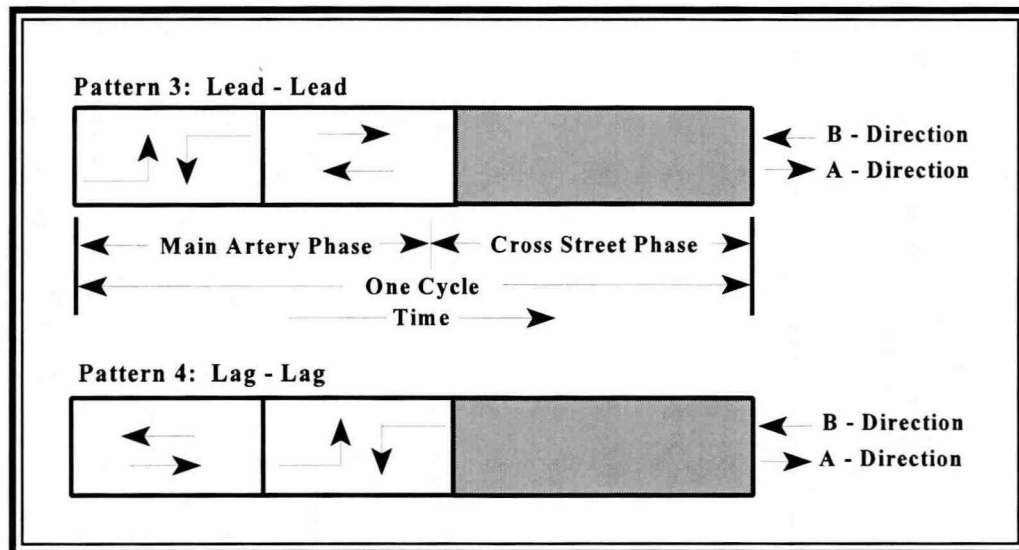
PASSER IV can analyze three mutually exclusive sets of left-turn phasing sequences for the two opposing arterial approaches at a traffic signal. These are: phasing with overlap, split phasing, and dual left-turns leading or lagging without overlap. Figures 1-5, 1-6, and 1-7 illustrate the three cases of left-turn turn phasing sequences. These three mutually exclusive cases have different critical pairs for calculating green splits. The example given in Figure 1-8 provides a comparison of the green splits and cycle lengths for these three phasing sequence options. It should be noted that, in general, the phasing sequence with overlap results in the smallest cycle length requirement and provides the maximum capacity. In addition, it provides maximum flexibility during optimization. We strongly recommended the use of phasing with overlap, unless public safety or hardware limitations require the use of phasing without overlap.



**Figure 1-5: Four Possible NEMA Phase Sequences with Overlap.**



**Figure 1-6: Split Phasing Sequences.**



**Figure 1-7: Lead-Lead and Lag-Lag Phasing Sequences without Overlap.**

### **Given the Following Data**

**Main Street runs North-South:**

**NB Splits — Through = 35 Seconds; Left-turn = 28 Seconds**

**SB Splits — Through = 30 Seconds; Left-turn = 25 Seconds**

**Cross Street runs East-West: Total Cross Street Phase Time = 40 Seconds**

### **Phasing With Overlap**

**Main Street Phase = Sum of Critical Phases**

**= Max {NB Through + SB Left, SB Through + NB Left}**

**= Max {35+25, 30+28} = Max {60, 58} = 60 Seconds**

**Cycle Length = Main Street Phase + Cross Street Phase = 60 + 40 = 100 Seconds**

### **Split Phasing**

**Main Street Phase = Sum of Critical Phases**

**= Max {NB Through, NB Left} + Max {SB Through, SB Left}**

**= Max {35, 28} + Max {30, 25} = 35 + 30 = 65**

**Cycle Length = 65 + 40 = 105 Seconds**

### **Lead-Lead or Lag-Lag Phasing Without Overlap**

**Main Street Phase = Sum of Critical Phases**

**= Max {NB Through, SB Through} + Max {NB Left, SB Left}**

**= Max {35, 30} + Max {28, 25} = 35 + 28 = 63**

**Cycle Length = 63 + 40 = 103 Seconds**

**Figure 1-8: Comparison of Green Splits for Various Phasing Options.**

The user can fix (simulate) a phasing sequence by selecting only one phasing sequence from the available options. When a user selects more than one option, PASSER IV chooses the phasing sequence that maximizes progression bandwidth efficiency.

### ***Signal offsets.***

The A-direction offset is the time difference between the start of the A-direction through green phase at one signal and the start of the A-direction through green phase at the adjacent signal. Offset in the B-direction is similarly defined. Holding all other signal timing parameters constant, A-direction offset for a two-way link also determines the B-direction offset. Figure 1-3 illustrates the A-direction offset between the first two signals. For undersaturated traffic conditions and when no queues are present at the downstream signal, ideal offset for a travel direction is equal to the link travel time (link distance divided by speed). PASSER IV optimization process attempts to select ideal offsets for all links. Offsets are the only signal timing parameter that cannot be simulated in PASSER IV.

### **Limitations and Future Enhancements**

PASSER IV is the only practical bandwidth-based signal timing optimization tool for networks. However, it has a number of shortcomings. Research is currently underway to overcome the following limitations:

- Inability to explicitly handle more than four approaches at an intersection
- Lack of an automated capability to calculate saturation flow rates
- The model applies to protected phasing only
- T-intersections must be input as four-approach intersections
- Offsets, and as a result existing signal timings, cannot be simulated
- An arterial should be completely one-way or two-way
- It does not have the ability to time a two-way arterial for one-way progression
- Special phasing patterns for interchanges (i.e. TTI 4-phase) cannot be modeled

# **PRACTICAL SESSION I: CODING A SIMPLE ARTERY**

## **INTRODUCTION**

This session provides a basic understanding of the PASSER IV User Interface as well as familiarity with the minimum data necessary to optimize signal timings on an arterial. In this session, we will use the data for the three-intersection arterial described in Figure 2-1. One key purpose of the exercises is to teach how to use PASSER IV to time signalized arterials when volume data is not available. By the end of this session, course participants will be familiar with the following topics:

1. Basic User Interface features, data coding, and optimization. These include :

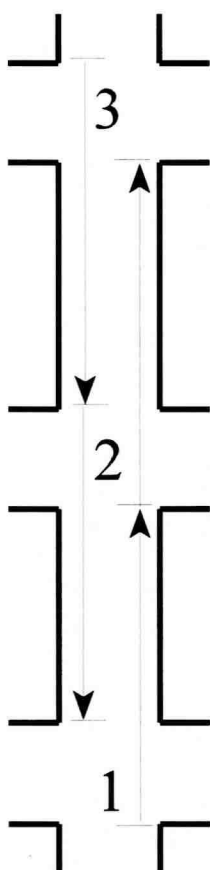
- Main-menu and main screen
- Status line
- Use of keys and mouse
- Creating new data files
- Data hierarchy, data coding and other key concepts, including:
  - Skeleton, mandatory, default, and optional data
  - A-direction selection
  - Basic coding of speed data
  - Signal identification number
  - NEMA numbering
  - Coding splits
  - Coding link lengths
- Saving data
- Loading an existing data file
- Running the optimization module
- Benefits of optimizing phasing sequences

2. Viewing/printing program output. Key items to be discussed include:

- Functions and features of the output mode
- Description of various sections of output:
  - Input data records and input data summary
  - Signal timing summary for the artery
  - Time-space diagram
  - Signal timing tables
  - Network solution summary

## SAMPLE ARTERIAL DATA

Case Data Name: ARTCASE1.DAT  
 Cycle Length: 100 Seconds  
 Artery A-Direction: Northbound  
 Cross Street A-Directions: Eastbound  
 Existing Phase Sequences: Lead-Lag with overlap  
 A-Direction Average Speed: 35 mph with 10% (3.5 mph) variation  
 B-Direction Average Speed: 35 mph with 10% (3.5 mph) variation



| Signal 3 | NB    |     | SB |    | EB |     | WB |     |
|----------|-------|-----|----|----|----|-----|----|-----|
| Data     | L     | T   | L  | T  | L  | T   | L  | T   |
| Splits   | .15   | .35 | .2 | .4 |    | .45 |    | .45 |
| Length   | 1500' |     |    |    |    |     |    |     |

| Signal 2 | NB    |     | SB    |     | EB |    | WB |    |
|----------|-------|-----|-------|-----|----|----|----|----|
| Data     | L     | T   | L     | T   | L  | T  | L  | T  |
| Splits   | .15   | .35 | .15   | .35 | .2 | .3 | .2 | .3 |
| Length   | 1000' |     | 1500' |     |    |    |    |    |

| Signal 1 | NB |    | SB    |    | EB |    | WB |    |
|----------|----|----|-------|----|----|----|----|----|
| Data     | L  | T  | L     | T  | L  | T  | L  | T  |
| Splits   | .1 | .4 | .1    | .4 | .2 | .3 | .2 | .3 |
| Length   |    |    | 1000' |    |    |    |    |    |

**Figure 2-1: Arterial Case Data.**

## FAMILIARIZATION WITH DATA CODING AND THE USER INTERFACE

We will begin by entering a portion of the arterial data described in Figure 2-1. The first part of this exercise will aid the course participants in becoming familiar with the basic elements of the user interface, data coding hierarchy, and the key data elements. Then, an existing data file will be loaded to discuss the remaining concepts. This data file contains all of the data described in Figure 2-1. At this time, please run PASSER IV.

### Basic Elements of the User Interface

The first line of the user interface displays the agency name and the version number of the program. Agency name is an alpha-numeric string that can be defined by the user by choosing the program configuration. The rest of the screen has three parts: the main-menu, the main-body, and the status line. The main-menu options control the operation of the program. The main-body provides space to display data entry screens and the program output. The status line provides context sensitive help and the name of the currently loaded data file. As you move the left and right arrow keys, you will see a description of the currently selected main-menu option. The user can also use the mouse to select a main-menu option. Any main-menu or sub-menu option can be selected by pressing the highlighted letter (hot-key) in the option name. At any time, the user can simultaneously press <Alt> and <X> keys to exit the program.

### Defining a New Data File

The user selected file name is up to eight characters in length. The file names follow the same convention as DOS file names. The program automatically adds the .DAT extension to the file name entered by the user. The user can define a new data file using the following steps:

- ☛ Action: Select New from the File menu.
- ☛ Action: Enter "ARTCASE" as the name of the file to be created, and hit <Enter>.

As soon as the user hits the <Enter> key, the program accepts the file name and automatically switches to the edit mode. In the following sub-section, we will describe how to code the data.

### Entering Data

PASSER IV assigns the following top-to-bottom (hierarchical) order to the data: system data, arterial data, and signal data. Figure 2-2 illustrates this hierarchical order. Function keys <F2> and <F3> provide for switching between the higher and lower levels in this hierarchy. In addition, the <PageUp> and the <PageDown> switch from one screen to the next within the current level. The <Esc> key can also be used to move one level up.



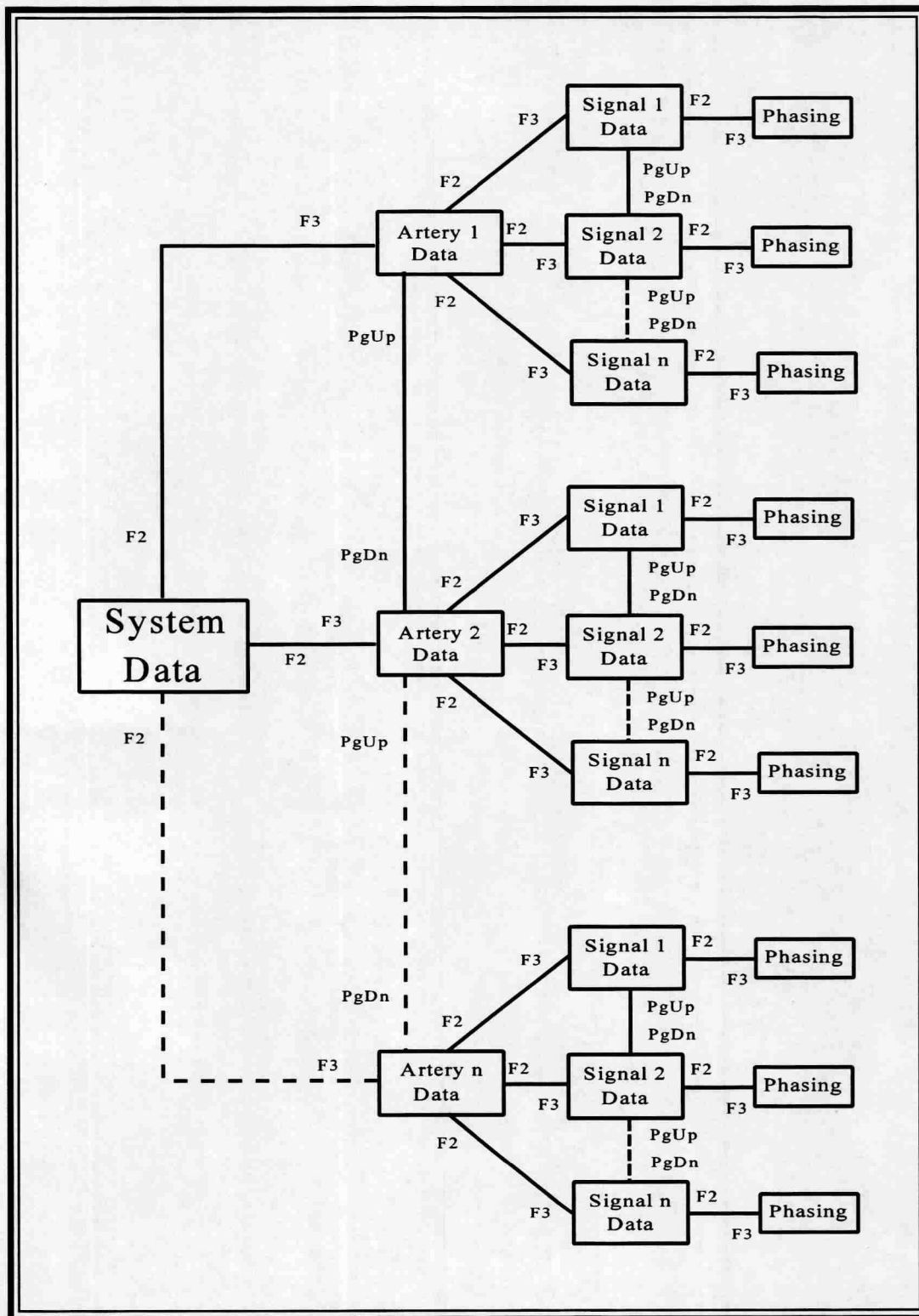


Figure 2-2: PASSER IV Data Hierarchy.

## ***System Data Screen***

This screen defines the systemwide data. The following default values are selected for a new data file:

- Run date = Today's date pulled from the computer memory.
- Number of arteries = 1.
- Number of Signals on the artery = 2.
- Cycle length = 100 seconds (same lower and upper limits).

In the above data, number of arterial and number of signals in the network must be correctly defined in order to proceed with the data entry. We refer to this type of data as skeleton data.

☛ Action: Change the number of signals to 3.

In PASSER IV, leaving a data field blank is not the same as having a zero (0) value for the data. Rather, it tells the program to automatically enter a default value, when applicable, in the field. Default values are of two types:

1. Programmed default values are those which remain unchanged from one run to another.
2. For some data fields, the default value is the data entered by the user in an associated field.

By default, the program selects English measurement units for the input data. The default value of measurement units for program output is the same as that for input data.

The students will notice that all fields for defining the master signal are blank. When these fields are left blank, the program automatically selects the start of A-direction through green at the first signal on the first arterial as the time for referencing offsets.

Initially, the program automatically selects options to print only input data summary and warning messages in the output report. With these options selected, PASSER IV only performs initial calculations, prints input data summary, and terminates without performing the optimization process. If there are any errors in the data, the program prints error messages regardless of the selected output options.

The remaining data (i.e. City name) are optional. The user can enter optional data for run identification purpose. Optional data is printed in the output report.

☛ Action: Press <F3> key to move one level down to the artery data screen.

## ***Artery Data Screen***

This screen defines data (including skeleton data) for an artery. In the following, we provide descriptions of these data.

Number of signals on this artery must be entered (skeleton data). Since we are entering data for a single artery problem, the program will automatically set the number of signals on the artery the same as the number of signals in the system (3).

The A-direction for the artery must also be entered (skeleton data). This choice is arbitrary and does not imply that the A-direction is more important than the other (B) direction. However, once the user selects an A-direction for an arterial, it dictates data entry order for signals on that arterial. This will be explained as we proceed. For our example problem, the A-direction is northbound.

☛ Action: Enter 'N' for the A-direction.

The program uses the time and distance scales specified for an arterial to draw the time-space diagram for that arterial. The default value of the time scale is 3 seconds per character. Regardless of the value entered here, the program can change this value if it is not sufficient to completely display both A and B-direction progression bands. The default value for the distance scale depends on the selected output units. For English (Metric) units, the default value for distance scale is 67 feet (20 meters) per line.

The artery priority defines the importance of this artery in relation to other arteries in the system. When the user enters a value of 101, the program calculated the priority based on the total volumes coded for the arterial. A blank field tells the program to ignore the priority relationships for this artery with other arteries.

The importance of one arterial direction over the other can be established by entering the A and B-direction priorities. Values of 101 request the program to internally calculate the priorities based on total directional volumes. The default values for each directional priority is 1. In this case, the program forces both bands to be of equal width. For the example in this session, we have assumed this to be the case.

The average speed fields for A and B-directions define the default average speed for all links in the respective direction. Average speed data must be entered for at least one of the two directions. If the user codes data for only one direction, the value for the other direction is assumed to be the same.

☛ Action: Enter 35 as the average speed for both directions.

The data fields for speed variation allow the user to specify the range of allowable speeds from which the optimization process can choose the best progression speeds. The range of allowable

speeds is set equal to the entered average speed  $\pm$  speed variation. If the speed variation field is left blank for a flow direction, the program automatically sets speed variation to be 10 percent of the speed value entered for that direction. If desires no speed variation for a direction, a value of zero (0) must be entered. We will leave these fields blank, telling the program to select speed variation values of 3.5 miles per hour for the links.

For individual links, the program can choose any progression speed in the specified range. This may cause large differences in optimal speeds between adjacent link in the same direction. The data for speed change defines a range to control this variation. A blank field tell the program to select a default value equal to 10 percent of the entered speed. In the following paragraph we explain this concept by using the data from our example.

The program can select optimal speeds of 31.5 mph and 38.5 mph for the two adjacent links in the same direction. The default (10 percent of 35) speed change value will restrict the maximum difference between these two speeds to be less than 3.5 mph. Thus, if the program selects a speed of 31.5 for the first link, it will not select a speed of more than 35 mph for the next link.

☛ Action: Press <F3> key to move one level down to the signal data entry screen. This will display the data screen for the first signal for the current artery.

### ***Signal Data Screen and Pop-up Window***

The signal data screen allows the user to enter approach data for a signal. The pop-up window lets the user choose from among the available phasing sequence options for the current signal. This section describes these data and explains related concepts.

The A-direction, entered earlier, plays a key role in how signal data are entered. The procedure is to enter the data starting from the first signal and moving to the next signal following the A-direction. Following this procedure, we will first define data for signal 1, then for signal 2, and finally for signal 3.

The program associates the data for each signal with a unique node identification number (skeleton data). This identification number does not need to be in a specific sequence. However, the node identification number must be entered once the program displays a signal data screen.

☛ Action: Enter 1 as the node identification number for the first signal.

NEMA 2 movement selection assigns NEMA numbers to geometric direction. The convention is to assign the number 2 to a specific through movement (i.e. westbound). Then, the program automatically assigns numbers 4, 6, and 8, to through movements in a clockwise rotation. Then, the program assigns the number 1 to the left-turn movement opposing movement 2. Finally, it assigns numbers 3, 5, and 7, to the remaining left-turn movements in a clockwise rotation. By default, the program assigns number 2 to the A-direction (northbound in our case) through movement.

PASSER IV uses the Artery 1 (Art1) and Artery 2 (Art2) A-directions to determine where to read the data for the two arterials crossing at this signal. In addition, these directions identify left-turn phasing sequence options. Except in a rare situation described in a later section, the Art1 A-direction is the same as the artery A-direction entered by the user on the artery data screen. The Art2 A-direction is dependent on two-factors:

1. If the signal is isolated in relation to the cross street approaches, the user should enter this direction based on where the data for cross streets will be entered and how the phasing sequences will be selected.
2. If a cross artery exists (the signal is linked to at least one more signal on the cross artery), and that artery is defined using the artery data screen, the Art2 A-direction will be the same as the A-direction for the cross artery.

The next group of data are what we call the link data. These data are read by the program according to the Art1 and Art2 A-directions. Although data can be entered for all links, the program only uses data for links connected to other signals on defined arterials. Key data in this group are link lengths.

☛ Action: Enter a value of 1000 for the southbound link.

Since this is the first signal on the arterial, we only need to define the length of the link from signal 2 to this signal.

The user enters the speed data only if they are different from the default values coded on the artery data screen. We will leave these fields blank.

Queue clearance times can be entered for progressed approaches if the user wants the program to advance the band to clear queues. The values for queue clearance times must be assessed through field studies. These times can be entered in fractions of the cycle length or seconds.

The next group of data are the approach data. Peak fifteen minute volumes (or demand) should be measured through field studies and multiplied by four to obtain the corresponding hourly rates. PASSER IV requires these flow rates. Saturation flow rate is a function of number of lanes and their assignments. These rates reflect the maximum physical capacity of traffic movements if the signal was green for the entire period. Volumes and saturation flow rates are used to calculate green splits. PASSER IV modifies the calculated splits to conform to the minimum green times supplied by the user.

As an alternate, the user can enter existing splits. The program modifies these splits to conform to any minimum green times entered by the user. Splits can be entered in seconds or as fractions of the cycle length, however, we recommend that splits be entered as a fraction of the cycle length.

- ☛ Action: Enter the splits provided for signal 1 in Figure 2-1.
- ☛ Action: Press <F3> to display the pop-up window for phasing sequence selection.
- ☛ Action: Enter a 'Y' (yes) for the Lead-Lag option for both main and cross street.
- ☛ Action: Press <F2> to move to close the pop-up window.

Up to this point, we entered all of the data we needed for each screen. For the next two signals, we will only enter the skeleton data.

- ☛ Action: Press <PageDown> key to move to the signal data screen for the second signal.
- ☛ Action: Enter '2' as the signal identification number.
- ☛ Action: Press <PageDown> key to move to the signal data screen for the third signal.
- ☛ Action: Enter '3' as the signal identification number.
- ☛ Action: Press <PageUp> or <PageDown> keys a few times to see how different signal data screens can be switched.

As you can see, once the skeleton data has been entered, the user can easily switch to any signal data screen and enter the remaining data. At this time, we will load a existing data file that contains the complete data given in Figure 2-1.

- ☛ Action: Enter the <F2> (or <Esc>) key three times to exit to the main-menu.
- ☛ Action: Select File option from the main-menu.
- ☛ Action: Select Open/Preview option from the File menu.
- ☛ Action: The program will inquire if you want to save the data (ARTCASE1) that you just coded. Press 'Y' to save this data.
- ☛ Action: Select the data file named ARTCASE1.DAT and hit <Enter>.

The above actions have loaded the selected data file into the program memory. Now we can run the optimization routine.

## Optimizing and Viewing Program Output

Now we will run the optimization routine and view the program output. In the process, we will make minor modifications to coded data and rerun the optimization routine to illustrate some additional concepts.

☛ Action: Select the Run option from the main-menu.

When the optimization routine finishes running, the program automatically selects the Output option.

☛ Action: Press the <Enter> key to view and/or print the program output.

☛ Action: Look through the program output.

In the output mode, the <PageUp> and the <PageDown> keys can be used to move one screen of text up or down. Simultaneously pressing one of the above keys together with the <Ctrl> key move a full page up or down. Further, up and down arrow keys can be used to browse through the output file one line at a time. In addition, the program provides a search function and a number of hot keys to allow easy access to the desired output section. A description of hot keys can be listed by pressing the <F5> key.

Browsing through the output, the users will notice the presence of horizontal lines. These lines identify the beginning of each page. Right below this line is the page title which displays the output file name and the page number. The users will also observe that the output contains only the input data summary and no optimization results. This is because we did not select the optimization flag on the system data screen. Now we will go back to that screen, modify output options, and rerun the optimization routine.

☛ Action: Escape to the main-menu, then select the Edit option. Now change the Input data summary flag to no by pressing <N>.

You will notice that the optimization flag has automatically changed to a 'Y.' This is because one of these options has to be selected as 'Y.'

☛ Action: Run optimization routine again, and select the Output mode.

At this time, we will use a hot key to go to the arterial section of the output.

☛ Action: Press <a>. Note, that the hot key is a lower case letter.

Pressing the hot key moved the cursor to the arterial section of the program output. This section prints the optimization results for the arterial. In the case of a multi-arterial network, one such section is printed for each arterial. The results printed in this section include: widths of directional



bands, arterial efficiency, arterial attainability, and the phasing sequences selected for this artery. Figure 2-3 shows these parts of the output. Referring to the guidelines provided in Section 1, the students will notice that this is not a very good solution. Notice that phasing sequences selected are the same as coded. In a short while, we will illustrate how this solution can be improved by optimizing phasing sequences.

```
ARTCASE1.OUT
```

```
PASSER IV VERSION 2.1
```

```
PAGE 5
```

```
*** ARTERY ***
```

```
NAME OF ARTERY:  ARTERIAL 1
```

```
NUMBER OF SIGNALS: 3
```

```
A-DIRECTION      : NORTHBOUND
```

```
*** ARTERY-WIDE INFORMATION ***
```

| ARTERY DIRECTION | BAND (% of Cycle) | BAND (Seconds) |
|------------------|-------------------|----------------|
| NORTHBOUND       | .1706             | 17.06          |
| SOUTHBOUND       | .1706             | 17.06          |

```
EFFICIENCY(%): 17.06
```

```
ATTAINABILITY(%): 48.75
```

```
*** INTERSECTION INFORMATION ***
```

| NODE NO. | CROSS STREET NAME | LEFT TURN PATTERN SELECTED | SIGNAL NO. |
|----------|-------------------|----------------------------|------------|
| 1        |                   | LEAD- LAG                  | 1          |
| 2        |                   | LEAD- LAG                  | 2          |
| 3        |                   | LEAD- LAG                  | 3          |

```
OBJECTIVE FUNCTION (C(1)B(1) + C(2)B(2)):
```

```
.341251
```

```
ALL PHASE STARTING TIMES ARE RELATIVE TO THE START OF N-BOUND GREEN
```

```
AT SIGNAL 1 ON ARTERY 1.
```

**Figure 2-3: Arterial Summary Section of Program Output.**

- ☛ Action: Using the shown arrow key, move a few lines down to see the progression speeds and travel times selected by the program.



Figure 2-4 shows this part of the output.

| ** PROGRESSION TIMES AND SPEEDS ** |      |            |        |         |            |        |         |      |
|------------------------------------|------|------------|--------|---------|------------|--------|---------|------|
| LINK                               |      | NORTHBOUND |        |         | SOUTHBOUND |        |         |      |
| -----                              |      | -----      |        |         | -----      |        |         |      |
| <=====                             |      | LINK       | TRAVEL | AVERAGE | LINK       | TRAVEL | AVERAGE |      |
| NODE                               | NODE | LENGTH     | TIME   | SPEED   | LENGTH     | TIME   | SPEED   |      |
| NO. <-->                           | NO.  | (FEET)     | (SECS) | (MPH)   | (FEET)     | (SECS) | (MPH)   |      |
| -----                              |      | -----      |        |         | -----      |        |         |      |
| 1                                  | <--> | 2          | 1000.  | 17.7    | 38.5       | 1000.  | 18.2    | 37.5 |
| 2                                  | <--> | 3          | 1500.  | 29.2    | 35.0       | 1500.  | 29.9    | 34.2 |
| -----                              |      | -----      |        |         | -----      |        |         |      |
| ENTIRE ARTERY:                     |      | 2500.      | 46.9   | 36.3    | 2500.      | 48.1   | 35.5    |      |
| -----                              |      | -----      |        |         | -----      |        |         |      |

**Figure 2-4: Optimal Progression Speeds Selected by PASSER IV.**

☛ Action: Simultaneously press <Ctrl> and <PageDown> keys.

This action will display the time-space diagram. We described the time-space diagram and its elements in Section 1 of this manual.

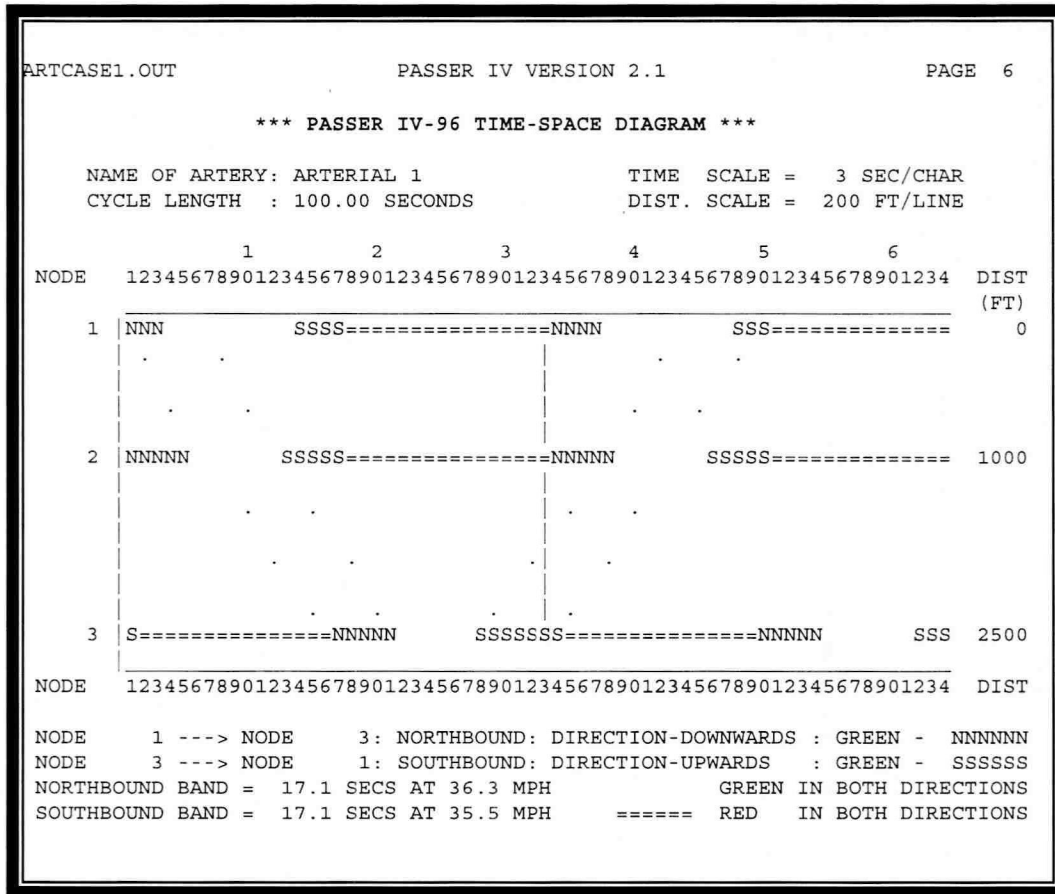
Before we proceed further, it would be appropriate to discuss suggestions for selecting the distance scale for the time-space diagram. The distance scale determines the length of the time-space diagram. Unnecessarily long diagrams are hard to interpret. Too short diagrams, on the other hand, may not show the bands. The optimal size of the diagram is such that the shortest link occupies four or five lines. For our example, a distance scale of 200 feet per line will produce a better time-space diagram for our problem. Let us take a moment to make this modification and observe the difference.

☛ Action: Go to the Edit option and change the distance scale value from 67 to 200.

☛ Action: Rerun the optimization routine and invoke the Output option.

☛ Action: Press <F2> to invoke the search function, enter the keyword 'space', and hit the <Enter> key.

This action displays the time space diagram shown in Figure 2-5. Note that this time-space diagram is more compact than the one we saw earlier. In addition to the progression bands, this section also displays cycle length, width of bands, and progression speeds.



**Figure 2-5: PASSER IV Time-Space Diagram.**

☛ Action: Press the hot key <t> to go to the signal timing summary section for the first signal.

Figure 2-6 illustrates the top portion of the signal timing page that you see on your screen. This section of the program output consists of signal timing information and measures-of-effectiveness (MOEs) for each signal. For each signal, PASSER IV prints this information on a separate page. Each page contains two tables. The first table displays signal timings in the form of phase intervals. In addition to allowing easy interpretation of phasing sequences, this format makes it easy to code the timings into a simulation program such as NETSIM. Below this table, is the offset and the reference movement information. This offset is the start of interval 1 in relation to the master approach. In the output, you will see a zero offset for the first signal. This is because signal 1 is the master signal and the master approach (A-direction through movement was assigned number 2) begins in interval 1.

\*\*\*\* SUMMARY OF PASSER IV-96 BEST SIGNAL TIMING SOLUTION \*\*\*\*

\*-[MASTER INTERSECTION] = NODE NO. 1 CYCLE LENGTH = 100.0 SEC

NODE NO. 1 : SIGNAL 1 ON ARTERY 1 AND A MINOR CROSS STREET  
 ARTERIAL 1 (S-N) (W-E)  
 NEMA 2 MOVEMENT : NORTHBOUND

===== PHASE AND CONTROLLER SETTING TABLE =====

|                    |      |      |      |      |      |      |
|--------------------|------|------|------|------|------|------|
| PHASE SEQUENCE     | 1    | 2    | 3    | 4    | 5    | 6    |
| NEMA PHASES        | 2+5  | 2+6  | 1+6  | 4+7  | 4+8  | 3+8  |
| PHASE SPLIT (SEC)  | 10.0 | 30.0 | 10.0 | 20.0 | 10.0 | 20.0 |
| PHASE SPLIT (%)    | 10.0 | 30.0 | 10.0 | 20.0 | 10.0 | 20.0 |
| PHASE INTERVAL (%) | .0   | 10.0 | 40.0 | 50.0 | 70.0 | 80.0 |

PHASE INTERVAL OFFSET (TO START OF INTERVAL 1): .0 SEC ( .0%).

PHASE REFERENCE: START OF N-BOUND PHASE (NEMA #2) AT NODE 1 + BASE= 0.

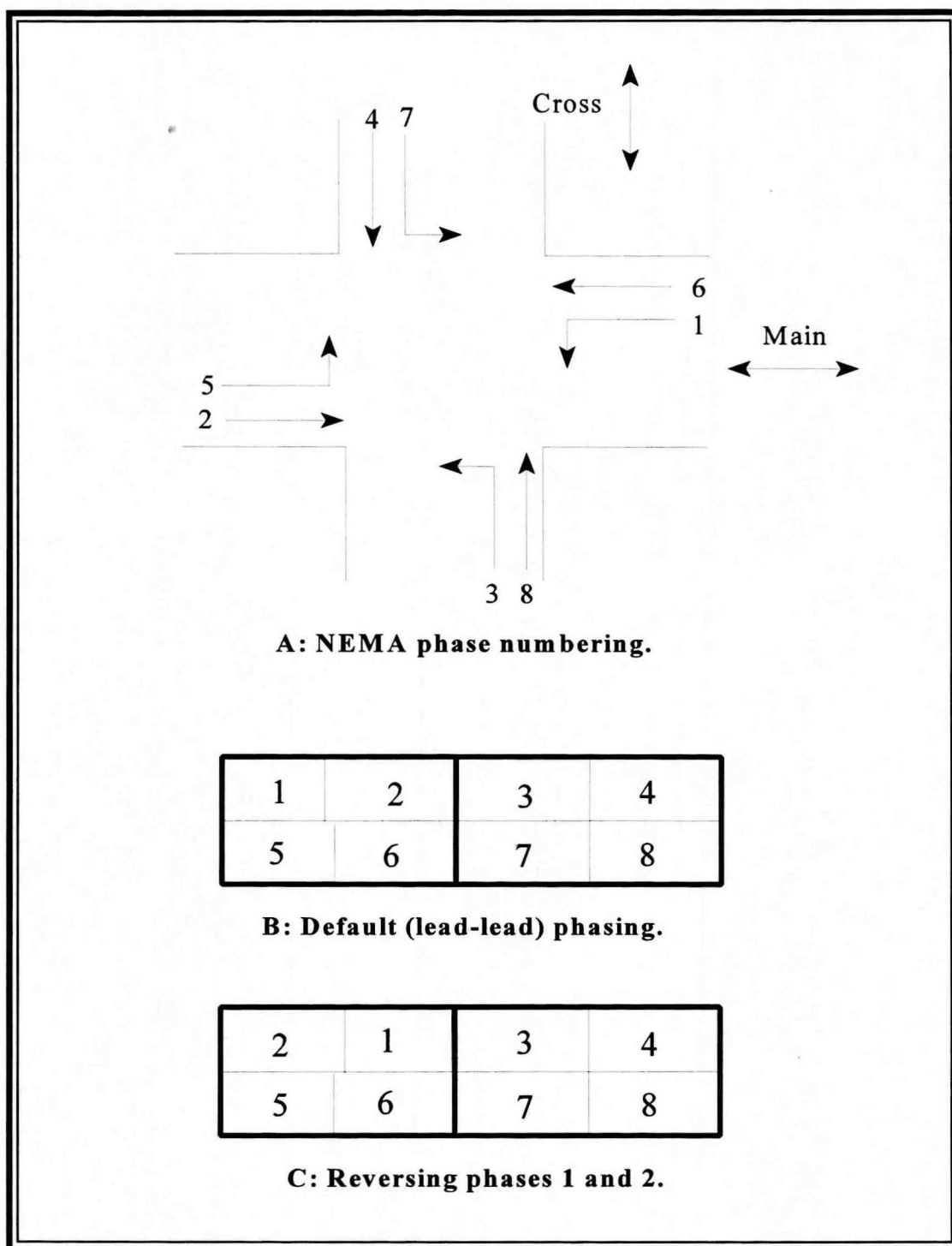
===== MOVEMENT-WISE MEASURES OF EFFECTIVENESS =====

|                  |       |       |       |       |       |       |       |       |
|------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| NEMA PHASE       | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     |
| SPLITS (SEC)     | 10.0  | 40.0  | 20.0  | 30.0  | 10.0  | 40.0  | 20.0  | 30.0  |
| PHASE REVERSAL   | \_Y\_ | \_Y\_ | \_Y\_ | \_Y\_ | \_N\_ | \_N\_ | \_N\_ | \_N\_ |
| OFFSET(%) TO BEG | 40.0  | .0    | 80.0  | 50.0  | .0    | 10.0  | 50.0  | 70.0  |

Figure 2-6: Signal Timing Summary Section.

☛ Action: Press <PageDown> to display the second table.

The first few lines of this table, shown in Figure 2-6, provide the signal timings for each NEMA movement of phase. The remainder of the table provides MOEs. PASSER IV did not print MOEs since we did not enter volume and saturation data. The signal timings are in a format ready for programming in a controller. These include: phase times, phase reversal information, and offsets. In an actuated controller, these phase times need to be programmed as maximum (Max) times. Reversing phases is a method of changing phasing sequences. By default, a dual-ring-8-phase NEMA controller implements lead-lead phasing sequences for both main and cross arteries at a signal. Alternate sequences can be programmed by reversing the order of conflicting phases on an artery. Figure 2-7 illustrates this concept. Here, reversing phases 1 and 2 resulted in lead-lag phasing for 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.



**Figure 2-7: Phase Reversal Concept for an Eight-Phase NEMA Controller.**

☛ Action: Press <Ctrl> <PageDown> to display the timings for the second signal.

Figure 2-8 illustrates what you see on this screen. Notice that the offset is non-zero for this signal.

```
ARTCASE1.OUT                                PASSER IV VERSION 2.1                                PAGE 8
```

\*\*\* SUMMARY OF PASSER IV-96 BEST SIGNAL TIMING SOLUTION (CONTINUED) \*\*\*

CYCLE LENGTH = 100.0 SEC

NODE NO. 2 : SIGNAL 2 ON ARTERY 1 AND A MINOR CROSS STREET  
ARTERIAL 1 (S-N) (W-E)  
NEMA 2 MOVEMENT : NORTHBOUND

===== PHASE AND CONTROLLER SETTING TABLE =====

| PHASE SEQUENCE     | 1    | 2    | 3    | 4    | 5    | 6    |
|--------------------|------|------|------|------|------|------|
| NEMA PHASES        | 2+5  | 2+6  | 1+6  | 4+7  | 4+8  | 3+8  |
| PHASE SPLIT (SEC)  | 15.0 | 20.0 | 15.0 | 20.0 | 10.0 | 20.0 |
| PHASE SPLIT (%)    | 15.0 | 20.0 | 15.0 | 20.0 | 10.0 | 20.0 |
| PHASE INTERVAL (%) | .0   | 15.0 | 35.0 | 50.0 | 70.0 | 80.0 |

PHASE INTERVAL OFFSET (TO START OF INTERVAL 1): 99.8 SEC ( 99.8%).  
PHASE REFERENCE: START OF N-BOUND PHASE (NEMA #2) AT NODE 1 + BASE= 0.

**Figure 2-8: Signal Timings for the Second Intersection.**

☛ Action: Press the hot key <s> to go to the next section.

Figure 2-9 illustrates what you see on the screen. This is the last section of the output report. It shows signal timing summary for each arterial and is useful for multi-arterial network problems.

|  |                               |                               |                       |                   |
|--|-------------------------------|-------------------------------|-----------------------|-------------------|
| **** NETWORK SOLUTION SUMMARY ****           |                               |                               |                       |                   |
|  | A-BANDWIDTH<br>PERCENT (SECS) | B-BANDWIDTH<br>PERCENT (SECS) | EFFICIENCY<br>PERCENT | ATTAIN<br>PERCENT |
| ARTERY 1:                                    | NB: 17.06 (17.06)             | SB: 17.06 (17.06)             | 17.06                 | 48.75             |
| AVERAGE NETWORK EFFICIENCY : 17.06 Percent   |                               |                               |                       |                   |
| AVERAGE DIRECTIONAL BANDWIDTH: 17.06 Seconds |                               |                               |                       |                   |
| NETWORK-WIDE CYCLE LENGTH : 100.00 Seconds   |                               |                               |                       |                   |

**Figure 2-9: Network Solution Summary.**

## Benefits of Optimizing Phasing Sequences

Thus far, the emphasis of exercises was to make the participants familiar with the PASSER IV user interface, data coding procedures for an arterial problem, and viewing and interpreting the program output. Now we will illustrate the importance of phasing sequence optimization in improving progression bands. First, we will edit the data to request the program to look at the full set of possible phasing sequences for each signal. Then, we will re-run the optimization routine. Finally, we will compare the results with those obtained earlier.

☛ Action: Press the <Esc> to move to the Main-Menu.

☛ Action: Invoke the Edit option.

☛ Action: Press <F3> three times.

This displays the phasing data screen for the first signal.

☛ Action: Press <Enter> three times. Then press <y> three times.

This results in the selection of the remaining three phasing sequence options for the artery (This Artery). For the cross street we can select only one phasing option. Therefore, we will not change that option. In fact, a particular phasing sequence on the cross street has no effect on the artery solution. PASSER IV only needs this information for printing the signal timing tables.

☛ Action: Press the sequence of keys <F2>, <PageDown>, and <F3> to get to the phasing data screen for second signal.

☛ Action: Press <Enter> three times, followed by <y> three times.

☛ Action: Similarly, change the phasing options for the third signal, and exit from the data editor.

☛ Action: Invoke the File menu and use the SaveAs option to save the modified data set as ARTCASE2

☛ Action: Run the optimization routine and invoke the output option.

☛ Action: Press <a> followed by <b>.

This displays optimal bandwidth and phasing information. Notice the program selected lag-lead phasing for the second signal. Also note that there is a significant improvement in progression bands. Figure 2-10 shows this section of the output.

☛ Action: Press <b> twice.

Figure 2-11 illustrates the time-space diagram that you see on the screen. Compare this time-space diagram with the one we obtained previously (Figure 2-5 on page 2-13), especially, offsets and link speeds.

| *** ARTERY-WIDE INFORMATION ***  |                   |                            |            |
|----------------------------------|-------------------|----------------------------|------------|
| ARTERY DIRECTION                 | BAND (% of Cycle) | BAND (Seconds)             |            |
| -----                            | -----             | -----                      |            |
| NORTHBOUND                       | .3208             | 32.08                      |            |
| SOUTHBOUND                       | .3208             | 32.08                      |            |
| -----                            |                   |                            |            |
| EFFICIENCY (%) :                 | 32.08             | ATTAINABILITY (%) :        | 91.64      |
|                                  |                   |                            |            |
| *** INTERSECTION INFORMATION *** |                   |                            |            |
| NODE NO.                         | CROSS STREET NAME | LEFT TURN PATTERN SELECTED | SIGNAL NO. |
| -----                            |                   |                            |            |
| 1                                |                   | LEAD- LAG                  | 1          |
| 2                                |                   | LAG -LEAD                  | 2          |
| 3                                |                   | LEAD- LAG                  | 3          |
| -----                            |                   |                            |            |

**Figure 2-10: Bandwidth Solution Corresponding to Optimized Phasing.**

### Changing Measurement Units

At the federal and state levels, the United States is pushing hard to switch the measurement system from English to metric. Engineers are under more and more pressure to use the metric system. It will take a while before engineers begin to think in metric; however, they are required to use this system for reporting purposes. PASSER IV provides a mechanism to facilitate this transition. Here, we will illustrate how to select the measurement units.

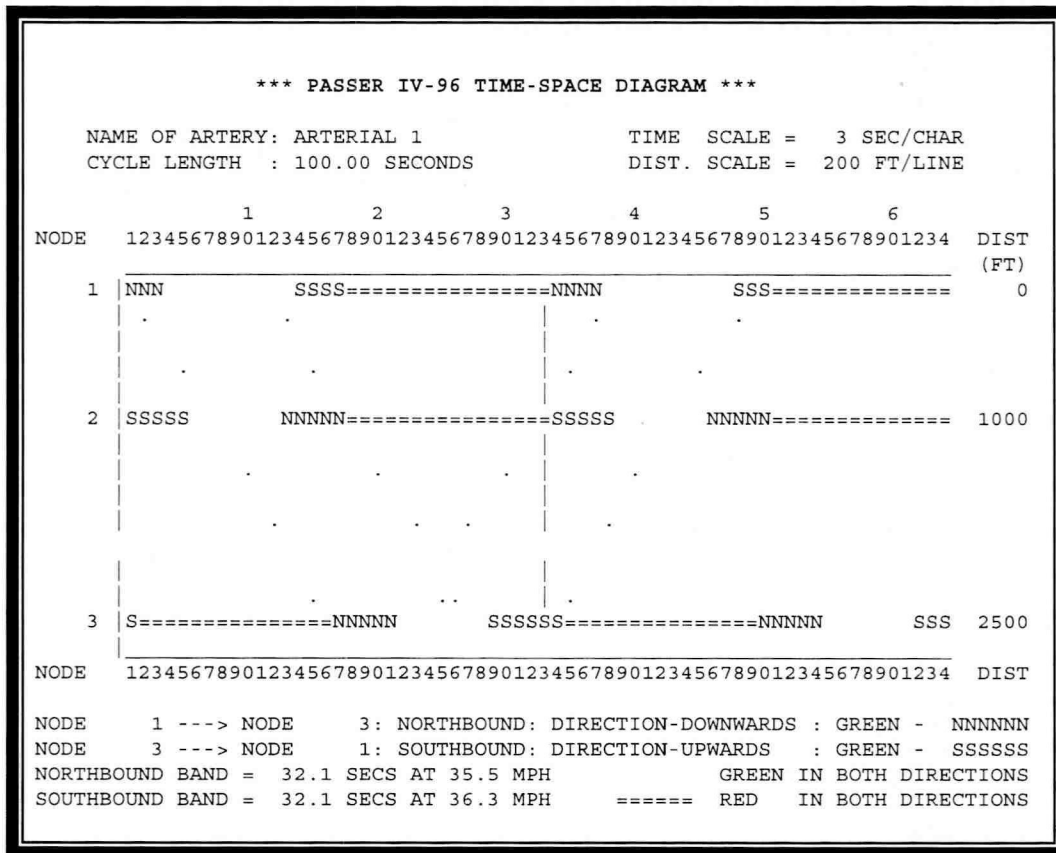
☛ Action: Invoke the Edit function.

☛ Action: On the system data screen, change the output units from English to metric.

☛ Action: Run the optimization routine and view output.

Notice how the program converted the output to metric units without having to modify the data.





**Figure 2-11: Time-Space Diagram for the Improved Solution.**

## **PRACTICAL SESSION II: CODING NETWORK DATA**

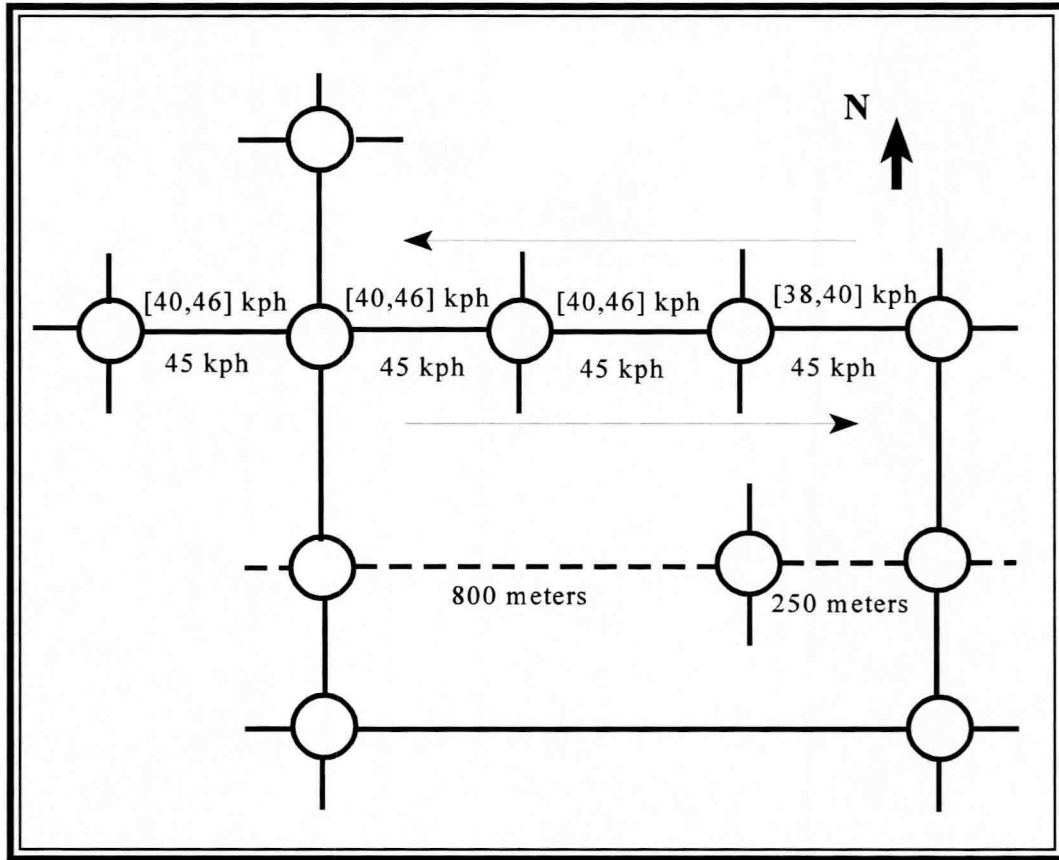
### **INTRODUCTION**

In the previous section, we used a simple arterial to teach the basics of using PASSER IV. In this section, we will use a sample network to describe how to enter data for a multi-arterial network. We begin with a description of the general data entry procedure, including reiteration of concepts described in the previous section.

PASSER IV requires that each signal be assigned a unique identification number. In addition, one direction for each arterial and cross street in the network must be identified as the A-direction. After this is done, the arterials in the network can be entered in any order. As user defines the arterials, the program automatically attaches a sequence number to each of them. These numbers identify arterials during data entry and edit modes as well as in the program output. The data for signals on an arterial, however, must be entered in a sequential order starting from the first intersection and proceeding to the last intersection following the A-direction. Although restrictive, this scheme allows the program to automatically determine the linkage of signals on the arterial. The node (signal) identification numbers enable the program to establish how arterials form the network and for determining closed loops in the network. In addition to the linkage data, the A-direction also tells the program where to read the approach data for each signal and how the phasing sequence selections are to be interpreted. The following is a step-by-step guide for coding the full network structure and a sub-set of approach data to illustrate the key concepts.

### **DATA PREPARATION, PLANNING, AND ORGANIZATION**

1. Identify signals and links in the network that will be timed as a coordinated system. Include only those signals that can be operated at the same cycle length. We suggest that the user exclude links with lengths of more than 1700 meters (about 1 mile).
2. Draw a graph of the network, north pointing up. Optionally, add link distances and link speeds on the graph. For this exercise, we will use the sample network shown in Figure 3-1.
3. Identify total number of intersections and arterials in the network. Write these numbers in the spaces provided in Table 3-1.
4. Write identification number for each signal on the figure (inside circles). This number can be from 1 to 999.
5. For each arterial and minor cross street, identify the A-direction. Add arrow heads to the graph to illustrate this information.
6. For each arterial, write the name and number of intersections in the space provided below the figure. Also, add arterial numbers to the graph.



**Figure 3-1: Sketch of a Sample Network.**

**Table 3-1: Network Information.**

|                           |                               |                             |
|---------------------------|-------------------------------|-----------------------------|
| <b>Network Name:</b>      |                               |                             |
| <b>Number of Signals:</b> |                               | <b>Number of Arterials:</b> |
| <b>Artery No.</b>         | <b>Artery Name (optional)</b> | <b>No. Of Signals</b>       |
|                           |                               |                             |
|                           |                               |                             |
|                           |                               |                             |
|                           |                               |                             |
|                           |                               |                             |

## Entering Skeleton Data

The data identified above is the basic data needed to define the network structure. These data are called skeleton data. Now, we will perform the following actions to enter skeleton data described above:

- ☛ Action: Select New from the File menu and enter 'NETCASE1' as the group name. This action automatically executes the Edit option.
- ☛ Action: At the System data screen, enter the number of arteries and signals in the network. Hit < F3 > to move to the data screen for the first artery.
- ☛ Action: At the Artery data screen, enter the number of signals and A-direction for the first artery.
- ☛ Action: Press < PageDown > key to move to the data screen for the next artery and enter the skeleton data for that artery. Finish entering skeleton data for all arteries. This step is complete when the artery data screen for the first artery reappears.
- ☛ Action: From any artery data screen, hit < F3 > to move to the data screen for the first signal on that arterial.
- ☛ Action: At the Signal data screen, enter the Node (signal) identification number.
- ☛ Action: Press < PageDown > to move to the next signal (following A-Direction of the artery) on the same artery, and enter the identification number for this signal.
- ☛ Action: Repeat the above step for all signals on the current artery. This step is complete when the screen for the first signal reappears.
- ☛ Action: Press < F2 > to move up to the Artery level.
- ☛ Action: Press < PageDown > and then < F3 > to define signals for the next artery. When done with this artery, repeat the process for the remaining arteries.

The remaining data can be entered either during the above steps or after all the skeleton data have been entered. In this exercise, however, we will use the Map option for entering the remaining data.

- ☛ Action: Press < Esc > a few times to exit the Edit function.

## Using the Map Option

☛ Action: From the Main-Menu, invoke the Map option.

The Map option requests the program to display a graph of the defined network. Only skeleton data is needed to define this graph. On the graph, the letter A, followed by a number (A#), identifies each artery. The number is the sequence number of the particular artery. For example, A3 identifies the third artery. In addition, the placement of the artery identifier also identifies the artery A-direction. The artery identifier, placed after the last signal in the A-direction, can be interpreted as an arrow head pointing toward the A-direction.

This graph is more than a display of the network structure. It has three types of selectable entities, signals, arteries, and system. From the graph, the user can access the data for each entity. This is done either by pointing and clicking the left mouse button on an entity or by using the arrow keys to select an entity and then pressing the <Enter> key. Pressing the <Esc> key exits back to the graph display. This exercise provides introduction by entering some data for the defined network.

☛ Action: Select the arterial and enter the default speed data shown in Figure 3-1.

☛ Action: Select the signal on the above artery that has different speed data, and enter these data.

In Figure 3-1, one artery is shown using dashed lines. This is a one-way artery. In PASSER IV, the user defines a one-way artery by entering a zero (0) priority for the closed direction. By default, the programs assumes that all arteries are two-way.

☛ Action: Change the artery from two-way to one-way. Observe how map display changed.

☛ Action: Move to the appropriate signal data screen and enter the link distances shown in Figure 3-1.

☛ Action: Select one signal, and enter the data provided in Table 3-2.

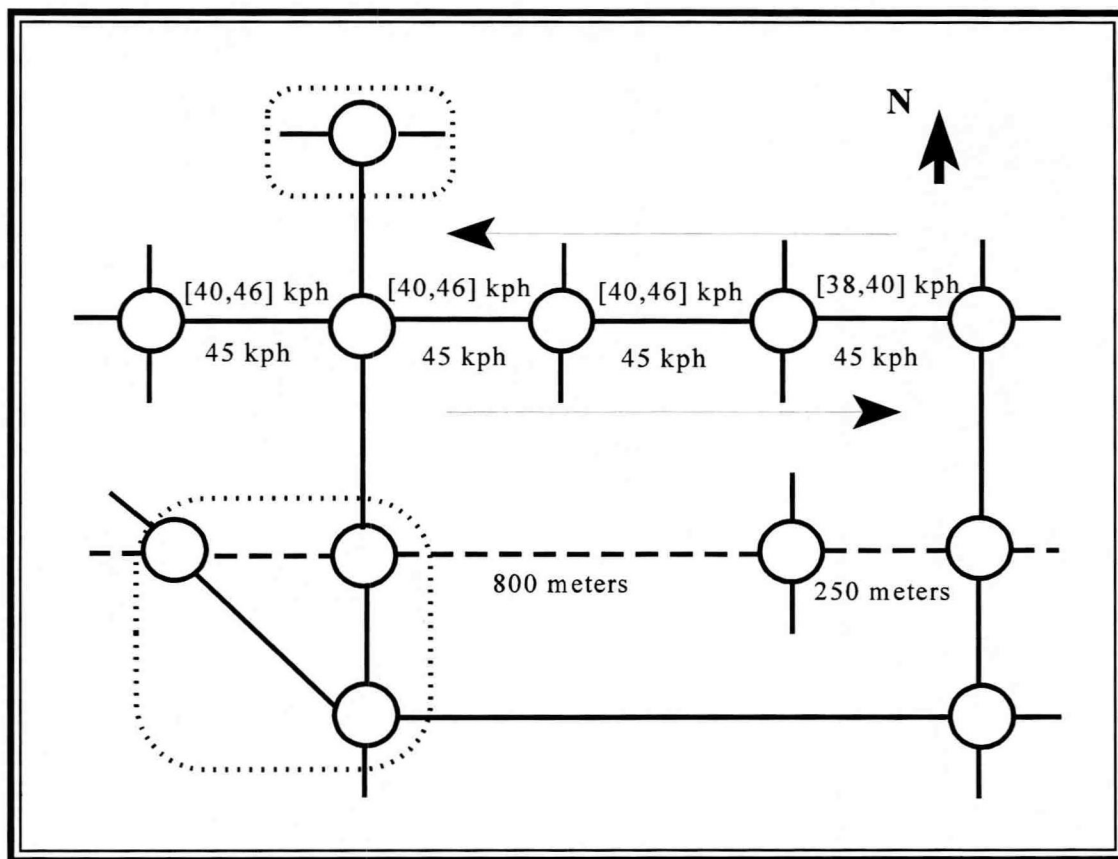
**Table 3-2: Volume and Saturation Flow Data for an Intersection.**

| Data Type | Northbound |      | Southbound |      | Eastbound |      | Westbound |      |
|-----------|------------|------|------------|------|-----------|------|-----------|------|
|           | Left       | Thru | Left       | Thru | Left      | Thru | Left      | Thru |
| Volume    | 250        | 400  | 250        | 400  | 300       | 500  | 250       | 350  |
| Sat.Flo.  | 1700       | 1800 | 1700       | 1800 | 3400      | 3600 | 2400      | 3600 |

- ☛ Action: For the above signal, enter phasing sequence selection for the main artery and cross street.
- ☛ Action: Exit to Main-Menu.

### Complicated Situations

Often times, PASSER IV users face what we call difficult data coding situations. We will discuss these situations using Figure 3-2. This figure describes the same network as in Figure 3-1; however, we have modified the network structure by adding a new signal common to two arteries. This addition has created a triangular sub-network. In addition, we have modified one intersection (the one in the northwest corner) by removing the southbound approach, making it a T-intersection.



**Figure 3-2: Modified Sketch of the Sample Network.**

### *Adding a New Signal*

Once the user finishes defining the network structure, it is not possible to make any changes to it using the Edit or Map functions of the Main-Menu. Rather, changes or modifications must be performed to the data file by using a text editor. The QuickEdit option of the Main-Menu provides a built in text editor for this purpose. A minimal understanding of the data file structure is sufficient for enabling the users to add or delete signals and arterials, and to change the signal identification numbers. The basic structure of the data file is given below in Figure 3-3.

|         |  |
|---------|--|
| NETWORK | This record is used to define the number of arteries and signals in the network.   |
| ARTERY  | This record A-direction and number of signals on the first artery. The data for each signal on this artery is defined the section starting with a SIGNAL record and by all records before the next SIGNAL record.    |
| SIGNAL  | The SIGNAL record defines the section containing data for the first signal on the current artery. In addition, it is used to supply signal identification number and other data general data for the current signal. |
| SIGNAL  | Second signal on the current artery.   |
| ....    |  |
| ....    |  |
| SIGNAL  | Last signal on the current artery.   |
| ARTERY  | Second artery.   |
| ....    |  |
| ....    |  |
| ARTERY  | Data for the last artery.  |
| ....    |  |
| ....    |  |
| END     | This record identifies the end of the data file.   |

**Figure 3-3: Structure of PASSER IV Data File.**

In this part of the exercise, we will add the new signal to the first artery. This artery is the one that has the smallest sequence number. It is dependent on how we assigned the sequence numbers earlier in this session.

- ☛ Action: Select an identification number for the new signal.
- ☛ Action: Invoke the QuickEdit option.



☛ Action: Insert a new SIGNAL record for the first artery.

This new record will be inserted either before the first SIGNAL record or after the last SIGNAL record for this artery. Why?

☛ Action: Enter the signal identification number on the new SIGNAL record.

The identification number must be entered, right justified, in columns 16 through 20. The text editor displays the location (row and column numbers) of the cursor at the top-right corner.

☛ Action: Press <Esc> to exit the text editor.

☛ Action: Press <y> to save changes to the data file.

The program will detect and fix some problems and issue a warning. The reason is that the change we just made, also changes the number of signals on the artery (ARTERY record) and in the system (NETWORK record); however, we did not make those changes.

☛ Action: Press <Enter> to accept corrections made by the editor.

The text editor is smart enough to automatically make the changes for you.

☛ Action: View the map.

### ***Defining a Triangular Sub-Network***

In order to define the triangular network shown in Figure 3-2, we will have to add the same signal on the second artery.

☛ Action: Invoke the text editor. Insert the new Signal record for the second artery and type in the same signal identification number as before.

☛ Action: Exit the text editor and view the graph of the network.

This addition illustrates one major limitation of the PASSER IV graph display capability. This limitation is that the program can only display horizontal and vertical lines. For a triangular network case, it requires that the second occurrence of the signal be labeled separately. In such cases, as you can see on the screen, the program displays the second occurrence in red color. This occurrence is not an entity in that signal data cannot be accessed from here. In order to access data, one must select the first occurrence of the signal. In the next version of PASSER IV, currently under development, this limitation will be removed.

Data for a signal forming a triangular network must be entered carefully. This is because the general directions of both arteries are the same (in our case, east-west). From the arterial perspective, each artery owns the same set of approaches (north/south pair or east/west pair) for its two flow directions. This, however, presents data coding problems because there is only one set of a pair of directions. Thus, in order to ensure correct data entry, the arterial directions at the signal must be interpreted from a local point of view. Once these directions are established, they are entered into the Art1 and Art2 A-direction fields on the signal data screen. The easiest method is to only change the Art2 A-direction. For our example, the Art2 A-direction will be either northbound or southbound, depending on the arterial A-direction. The remaining data are entered according to the A-directions selected for Art1 and Art2.

☛ Action: From the map, access the signal data screen for this signal.

☛ Action: Make the appropriate changes using the signal data provided in Table 3-2.

### *Coding a T-intersection*

One major limiting assumption made during the PASSER IV development was that an arterial must be either fully one-way or fully two-way. Due to this, PASSER IV requires that data for both through arterial approaches be defined for all signals on a two-way arterial. Therefore, data for arterial directions must be entered in such a way that it fools the program into interpreting the signal as having both approaches. We will use the data given below to describe the possible options.

**Table 3-3: Volume and Saturation Flow Data for a T-intersection.**

| Data Type       | Northbound |      | Southbound |      | Eastbound |      | Westbound |      |
|-----------------|------------|------|------------|------|-----------|------|-----------|------|
|                 | Left       | Thru | Left       | Thru | Left      | Thru | Left      | Thru |
| <b>Volume</b>   | 250        | 400  |            |      | 300       | 500  | 250       | 350  |
| <b>Sat.Flo.</b> | 1700       | 1800 |            |      | 3400      | 3600 | 2400      | 3600 |

For the data given above, the recommended option is to code the volume and saturation flow data for the northbound left-turn movement in the southbound through movement fields.

## PRACTICAL SESSION III: ADVANCED TOPICS

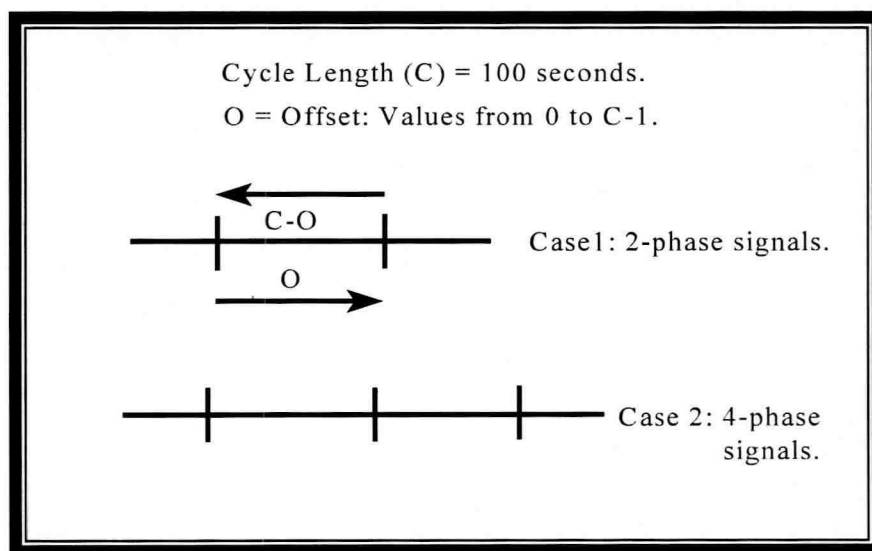
### INTRODUCTION

In this session, we will discuss advanced topics related to PASSER IV. Users' familiarity with the concepts presented here will enable them to use the program more effectively. A portion of this session will be devoted to theoretical concepts. The rest of the session will focus on the introduction of advanced features. These topics include:

- Complexity of signal timing optimization problems
- Issue of multiple solutions
- Vehicular emissions and other measures-of-effectiveness
- Integer Programming Topics
- Fine Tuning of PASSER IV Solutions.

### COMPLEXITY OF SIGNAL TIMING OPTIMIZATION PROBLEMS

Refer to the two arterial cases illustrated in Figure 4-1. Case 1 is a two-way arterial with two signals. Both signals on this arterial are two-phase signals. Case 2 is a two-way arterial with three multi-phase signals. In addition, we assume that all signals on the two arterials are fixed-time and are being operated at a 100 seconds cycle length.



**Figure 4-1: Illustration of Problem Complexity.**

The following are some basic facts for Case 1:

- The offset for eastbound link can be selected from 100 different possibilities (0 sec., 1 sec., 2 sec., 99 sec. etc.). This choice depending on the objectives of coordination as well as traffic conditions in the two flow directions.
- Selection of an offset (O) for the eastbound link also establishes an offset for the westbound link (C-O).
- The sum of offsets for the two links is equal to the cycle length ( $O + (C-O) = C$ ). This is a natural condition for any pair of coordinated signals.
- If we change the operation of arterial approaches at the first signal from two-phase to multi-phase, and phasing sequence is to be optimized, the number of possible solutions will change to 400 (4 possible phases and 100 offsets). If the same is done for the second signal, the number of possibilities will increase to 1600 ( $4 \times 400$ ).

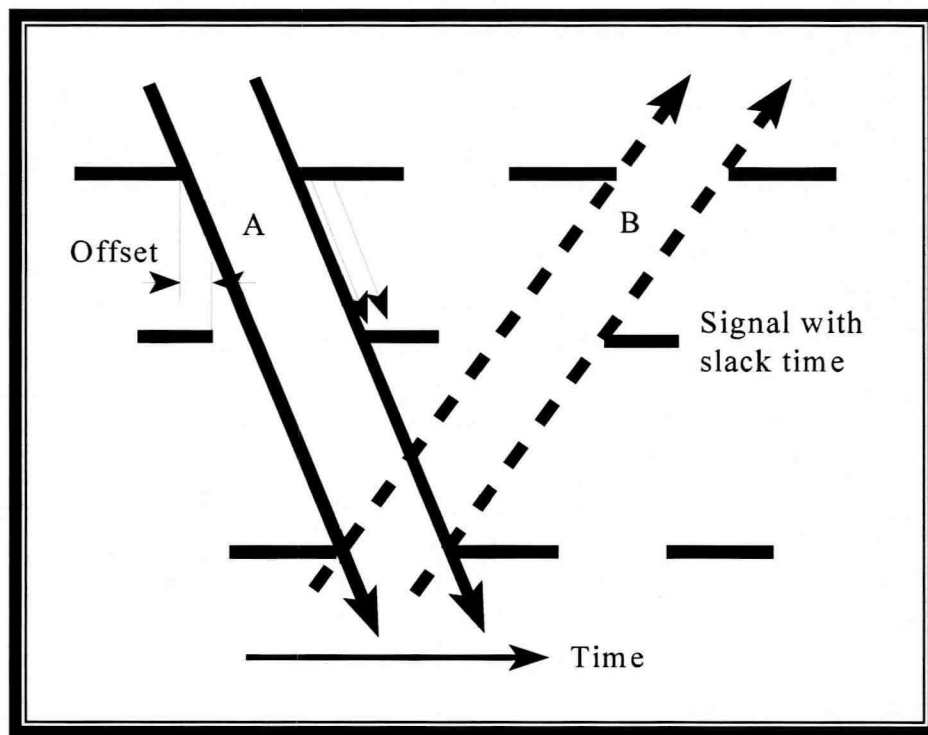
Adding a link to the above arterial results in Case 2. This problem has 100 possible offsets for each of the two links and 4 phasing sequence possibilities for the arterial approaches at each signal. This results in 640,000 possible choices for signal timing parameters.

The above example illustrates that the number of possible solutions grow exponentially with the size of the problem. If we add the cycle length optimization, it further adds to this complexity. For network problems, there could be millions of possible solutions. Fortunately, PASSER IV has an intelligent optimization strategy that only investigates a very small subset of solutions for a given signal timing problem.

## ALTERNATE SOLUTIONS

As explained above, all signal timing optimization problems have a large number of solutions. Which solution is chosen as the best depends on whether the objective of timing signals is to maximize progression or delay. When the objective of coordinating traffic signals is to minimize total system delay, equal weight is given to the progression of all traffic movements. This generally results in an excessive number of stops to through traffic. Bandwidth optimization on the other hand, gives higher priority to through traffic. For this reason, practitioners in Texas prefer coordination of traffic to maximize through progression. Except in rare situations (through traffic only or insignificant turning traffic from side streets at the upstream signals), progression bandwidth maximization does not result in a minimum delay solution.

Further, regardless of the objective of coordination, there might be multiple optimal solutions for a given problem. We use Figure 4-2 to explain this concept for progression bandwidth optimization problems. This figure shows a time-space diagram for a three-signal arterial with two-phase signals.



**Figure 4-2: Time-Space Diagram for an Arterial.**

The following information can be obtained from Figure 4-2:

- This time-space diagram corresponds to a timing plan that resulted in maximum efficiency and 100 percent attainability for the assumed signal timing parameters.
- The first and last signals are constraining the bands in both directions.
- The signal in the middle is constraining the trailing (left-side) edges of both bands.
- The middle signal has slack green time before the leading edges of the bands.

The existence of green-time slack at the leading edges of the bands implies that the signal offset can be changed by one second increments until the beginning of green phase coincides with the leading edges of the bands. Each increment in the offset results in an alternate timing plan (solution) with the same maximum bandwidth efficiency as before. Total system delay to traffic, however, can be different for each of these alternate timing plans. The magnitude of this difference is dependent on the traffic conditions. Since the PASSER IV model does not consider delay, it cannot differentiate

between these alternate timing plans and can select any one of them depending on a number of factors that will not be discussed here.

The above example illustrates one factor that can lead to alternate optimal solutions for an arterial. Other factors that can produce alternate optimum solutions are:

- Different set of phasing sequences,
- Alternate cycle lengths, and
- Alternate allocation of efficiencies between the two flow directions.

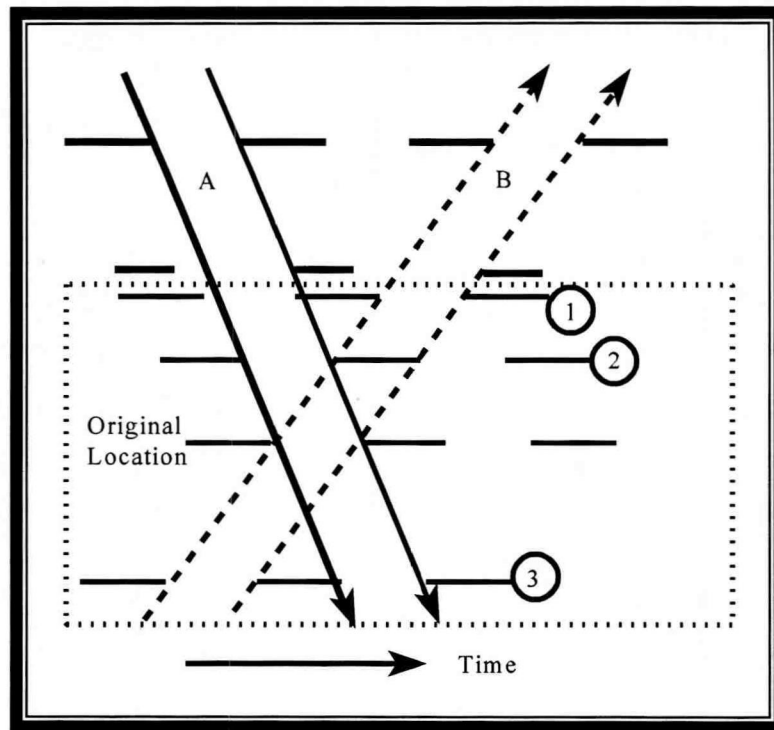
The same factors also apply to arterials in a multi-arterial network. In addition, alternate solutions in networks can also result from different allocations of efficiencies between arterials. For instance, in many cases, it is possible to increase efficiency for one arterial at the expense of another artery without decreasing the total network efficiency.

### **EFFECTS OF SIGNAL LOCATION ON PROGRESSION**

Distance between traffic signals has a major impact on the quality of two-way progression. Figure 4-3 illustrates this concept. Figure 4-3, obtained by modifying Figure 4-2, shows three alternate locations for the third signal. It illustrates the following facts:

- If the third signal were located at position 1, we would have gotten a solution very close to the optimal solution (100% attainability).
- If the signal were located at position 2, only one-way progression would have been possible. A similar situation with a slightly larger red-phase would have resulted in a no solution scenario. In such cases, PASSER IV reports that the problem is infeasible. The infeasibility case presented here is extremely rare for arterial problems; however, if such a situation arises, the user should time signals for one-way progression in the direction with higher traffic flow. Unfortunately, PASSER IV does not provide an option to request one-way progression for a two-way artery. PASSER IV does not provide this option because of the fact that it occurs rarely and it is trivial to time an arterial for one-way progression. All one has to do is to set signal offsets to match the travel time on the associated link.
- All locations between 1 and 2 would have produced solutions with lower attainability.
- Location 3 would have resulted in a solution with 100 percent attainability.

Thus, progression analysis should be used in city street planning to avoid placement of intersections at bad locations. In addition, traffic progression should be taken into considerations when making decisions to install new signals at mid-block locations.



**Figure 4-3: Significance of Signal Location.**

## **PROBLEM FORMULATION AND OPTIMIZATION**

For a given problem, PASSER IV translates the constraints on signal timing parameters into a mathematical form. These constraints, together with an objective function are called a mathematical formulation. The objective function is the sum of variables representing efficiencies for all flow directions. Each constraint consists of a linear combination of continuous and/or integer variables and has the following form:

$$A + B = 10$$

PASSER IV systematically searches for those values of variables (a solution) that satisfy all constraints. For a problem, there could be many solutions that satisfy all constraints. The optimization process selects, as optimal solution, the feasible solution that results in maximum total efficiency.

### **Search Procedure**

The optimization algorithm stores the problem formulation in a matrix (one row per constraint). Initially, all variable are assumed to be continuous. The resulting formulation is a linear program (LP). Each step required to solve a linear program is called an iteration. An iteration consists of



several arithmetic operations (addition, subtraction, multiplication, and/or division) on all entries in a row. The time required to perform one iteration depends on the number of entries in a particular row and is a function of the size of the problem. For instance, one iteration for an arterial problem with ten signals will take more time than one iteration for an arterial problem with three signals. Optimizing a linear program requires several iterations. The number of these iterations also depends on the problem size.

The optimal solution to the LP establishes an upper bound on the solution. In other words, this is the best solution that can be achieved for the signal timing problem. Then, the branch-and-bound (BB) algorithm kicks in to ensure that integer variables have whole numbers as their values. In order to illustrate this concept, we use the following example:

**Example:** Assume that the decision sought is to determine the number of trucks needed by a company for its delivery operation. LP results in 2.3 trucks. This is not an acceptable answer. This situation is resolved by dividing the original problem into two subproblems (branches) as follows:

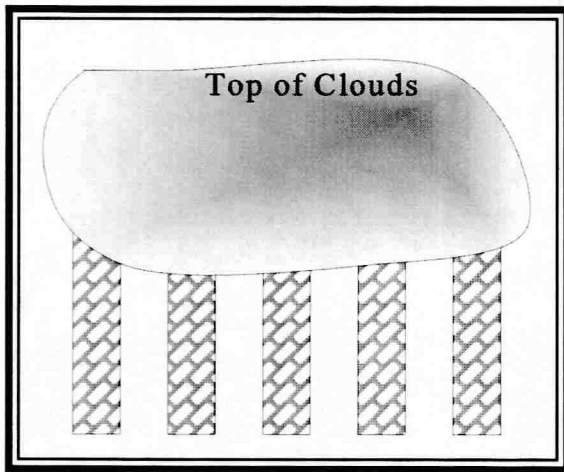
- Problem 1: Number of trucks must be less than or equal to 2.
- Problem 2: Number of trucks must be equal to or more than 3.

Then, each problem is solved independently and the best solution is selected.

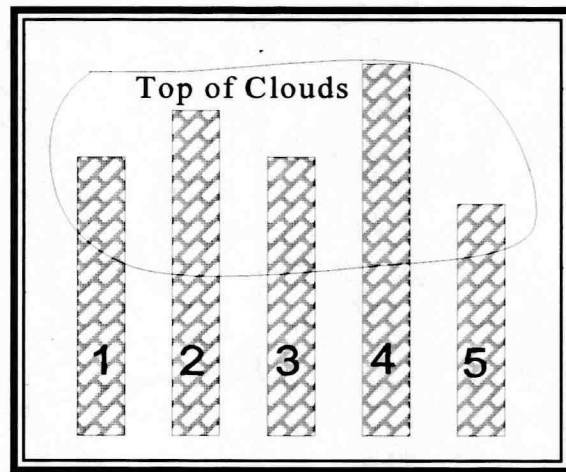
In the case of a problem with multiple integer variables, hundreds of branches may need to be created. When a branch satisfying all integer variables is found, its solution establishes the current best solution. The algorithm then searches for a solution that is better than the current best until it reaches the target. In this process, it ignores (fathoms) any branch that does not have the potential to produce a better solution. In the following, we describe the essence of the search procedure using an analogy.

Assume that we need to find the tallest building in a downtown area covered by thick clouds. A graphical illustration is provided in Figure 4-4. First, a search crew uses an airplane to establish the height of the cloudtop and the fact that the tallest building is not higher than the cloudtop. This process is analogous to that of solving an LP to obtain the upper bound. Then, a helicopter is sent to measure heights of the buildings from close proximity. Refer to Figure 4-5 for this explanation. The helicopter crew chooses to start from building 1 and performs the following steps:

1. The helicopter rises to the top of building 1 and marks it as the tallest building.
2. From that altitude, they can see that building 2 is higher. So the helicopter climbs to that altitude and moves closer to building 3, labeling it the tallest building.
3. From the current altitude, they do not even see building 3. The next jump is to building 4. Since this height is the same as the height of the clouds, the search ends here.



**Figure 4-4: Upper-Bound Analogy.**



**Figure 4-5: Finding Tallest Building.**

Had the helicopter crew started from building 5, they would have finished sooner.

### **Available Solution Strategies**

PASSER IV can optimize a problem using three strategies; all use the branch-and-bound algorithm explained above. These strategies are:

- One Step Strategy: This strategy simultaneously solves for all signal timing parameters. Given enough computer (CPU) time, it always finds the best solution. However, it may take hours of CPU time. This strategy applies to all types of problems.
- Two-Step Strategy: This strategy determines all offsets at stage 1. Then, it determines signal phasing sequences. It is ten times faster than the one-step strategy and produces the best solution most of the time. It is applicable to any problem that requires at least one phasing sequence selection decision. We recommend this strategy for arterial problems.
- Three-Step Strategy: First it, determines offsets for all links. Then it determines offsets for closed loops. Finally, it determines phasing sequences. This strategy is up to 99 times faster than the one-step strategy. It is applicable only to multi-arterial networks with at least one closed loop. Although the results produced are not as good as the above two strategies, we recommend that this strategy be used for closed loop networks.

## ILLUSTRATION USING A SAMPLE DATA SET

In this section, we will use a sample data set to illustrate the optimization related concepts described above. The sample data file has been prepared using real data for a five-arterial, nine-intersection network from California. In addition to the above concepts, we will discuss the following topics:

- Use of the Batch mode
- Emissions Tables
- Options Menu
- Cycle length minimization
- Obtaining multiple solutions
- Description of MOEs
- Fine tuning of PASSER IV generated bandwidth solutions

☛ Action: Load W509.DAT

☛ Action: Run and View Output

☛ Action: Look at optimization performance plot

☛ Action: Press <t>, followed by <PageDown> to look at a signal timing table.

Figure 4-6 provides the table you see on your screen. Since all data were entered for this problem, the program printed the MOEs. PASSER IV calculates delay for all progressed through movements using the same procedure as PASSER II. The Highway Capacity Manual (HCM) method is used to calculate the delay for non-progressed through movements, the delay for all left-turn movements, and volume-to-capacity ratios (v/c).

Stops, queue lengths, fuel consumption, and vehicular emissions are estimated using the calculated delay values, travel times and volumes. The estimation of vehicular emissions require the specification of emissions factors.

☛ Action: Display an emissions table using the program options. Provide an explanation of these emissions factors.

The threshold values given in Table 4-1 are used to calculate delay levels-of-service (LOS) and v/c ratio LOS

☛ Action: View last page of the output report.

Figure 4-7 illustrates the last page of output containing the network solution summary.

| ===== MOVEMENT-WISE MEASURES OF EFFECTIVENESS =====      |       |        |       |        |       |       |       |       |
|--|-------|--------|-------|--------|-------|-------|-------|-------|
| NEMA PHASE   | 1     | 2      | 3     | 4      | 5     | 6     | 7     | 8     |
| SPLITS (SEC)   | 10.0  | 36.4   | 10.6  | 33.0   | 13.3  | 33.1  | 18.6  | 25.0  |
| PHASE REVERSAL   | \ Y / |        | \ N / |        | \ N / |       | \ N / |       |
| OFFSET(%) TO BEG   | 49.9  | 9.5    | 61.0  | 72.8   | 9.5   | 24.2  | 61.0  | 81.7  |
| STOP DEL (SEC/VEH)                                       | 50.9  | 37.8   | 79.9  | 8.6    | 30.5  | 18.7  | 41.3  | 6.7   |
| APPR DEL (SEC/VEH)                                       | 66.2  | 49.1   | 103.9 | 11.1   | 39.7  | 24.3  | 53.7  | 8.7   |
| DELAY LOS  | E     | D      | F     | B      | D     | C     | E     | B     |
| VOLUME (VPH)   | 132   | 1936   | 104   | 622    | 120   | 892   | 200   | 348   |
| SAT FLOW (VPHG)  | 2400  | 6000   | 1500  | 3000   | 2400  | 6000  | 1500  | 3000  |
| V/C RATIO  | .82   | .90    | .94   | .64    | .49   | .46   | .82   | .50   |
| V/C RATIO LOS  | D     | E      | E     | B      | A     | A     | D     | A     |
| LINK LEN (FEET)  | -     | 840    | -     | 2600   | -     | -     | -     | 2700  |
| TRA TIME (SECS)  | -     | 11.9   | -     | 50.6   | -     | -     | -     | 50.0  |
| AVG SPEED (MPH)  | -     | 48.0   | -     | 35.0   | -     | -     | -     | 36.8  |
| AVG QUEUE (VEH)  | 4.3   | 33.0   | 5.7   | 10.5   | 2.7   | 15.1  | 5.3   | 6.7   |
| MAX QUEUE (VEH)  | 4.4   | 47.7   | 5.9   | 13.3   | 2.8   | 17.7  | 5.9   | 7.5   |
| STOPS (PER VEH)  | 1.21  | .89    | 2.05  | .77    | .85   | .72   | 1.07  | .78   |
| FUEL CON (GAL/HR)  | 1.8   | 74.9   | 65.4  | 33.9   | 44.9  | 4.4   | 34.9  | 30.6  |
| TOT VOC (GR/HR)  | 97.3  | 1652.6 | 242.4 | 806.2  | 89.9  | 241.9 | 353.9 | 442.5 |
| TOT CO (GR/HR)   | 833   | 15785  | 2393  | 8790   | 871   | 2070  | 3637  | 4851  |
| TOT NOX (GR/HR)  | 10.2  | 1219.9 | 187.7 | 1009.7 | 74.3  | 25.4  | 334.6 | 589.3 |
| TOTAL INTERSECTION DELAY (VEH-HRS/HOUR): 44.96           |       |        |       |        |       |       |       |       |
| TOTAL FUEL CONSUMPTION (GALS/HR): 290.9                  |       |        |       |        |       |       |       |       |
| TOTAL EMISSIONS (KG/HR): VOC: 3.93, CO: 39.23, NOX: 3.45 |       |        |       |        |       |       |       |       |

**Figure 4-6: Signal Timing Table Showing Measures-of-Effectiveness.**

☛ Action: Press <Esc>, and invoke the Options menu.

The options menu provides selections related to the optimization process. These include: upper limit on iterations, selecting the optimization strategy, specifying cycle length minimization, selecting the maximum number of solutions to be printed, and setting tolerances.

Of all the tolerance values, TOLF is the one that users will utilize most. For a signal timing problem, there might be dozens of solutions with little differences. In the tallest-building analogy, there might be a group of buildings with minor differences in heights. In those cases, we can reduce search time by requesting the program to only accept a new solution if it is X percent better than the current lower bound. This is accomplished by specifying a value of X/100 for TOLF.

**Table 4-1: Threshold Values for Level-of-Service.**

| Level-Of-Service                                  | Delay Threshold<br>(Sec./Veh.) | V/C Ratio Threshold |
|---|--------------------------------|---------------------|
| A   | [0,6.5)                        | [0.0,0.6)           |
| B   | [6.5,19.5)                     | [0.6,0.7)           |
| C   | [19.5,32.5)                    | [0.7,0.8)           |
| D   | [32.5,52.0)                    | [0.8,0.85)          |
| E   | [52.0,78.0)                    | [.85,1.0)           |
|   | [78.0,999)                     | [1.0,5.0)           |
| [X,Y) means all values equal to X and less than Y |                                |                     |

| **** NETWORK SOLUTION SUMMARY **** |                               |                               |                       |                   |
|------------------------------------|-------------------------------|-------------------------------|-----------------------|-------------------|
|                                    | A-BANDWIDTH<br>PERCENT (SECS) | B-BANDWIDTH<br>PERCENT (SECS) | EFFICIENCY<br>PERCENT | ATTAIN<br>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                   |                               |                       |                   |

**Figure 4-7: Network Solution Summary.**

The user can request the program to save a specified number of best solutions. This is done by choosing the number of solutions to be save for each step. In the case of two or three-step methods, the number for the last step refers to the program output. This is because the optimization process is not complete until the end of the last step.

- ☛ Action: Change number of solutions to 3,3,3, and explain the significance of these numbers.
- ☛ Action: View output report for each solution saved.

Figure 4-8 presents a summary of solutions from all the reports. Note that the last solution is the best solution.

- ☛ Action: Explain the AAP-like feature of PASSER IV.
- ☛ Action: Illustrate the Batch mode.

| **** NETWORK SOLUTION SUMMARY ****            |    |                               |                               |                       |                     |
|---|----|-------------------------------|-------------------------------|-----------------------|---------------------|
|   |    | A-BANDWIDTH<br>PERCENT (SECS) | B-BANDWIDTH<br>PERCENT (SECS) | EFFICIENCY<br>PERCENT | ATTAIN<br>PERCENT   |
| -----   |    |                               |                               |                       |                     |
| <b>Report 1</b>                               |    |                               |                               |                       |                     |
| ARTERY  | 1: | EB: 55.03 (49.53)             | WB: 55.01 (49.51)             | 55.02                 | 99.99               |
| ARTERY  | 2: | EB: 2.12 ( 1.91)              | WB: 1.03 ( .93)               | 1.57                  | 4.23                |
| ARTERY  | 3: | SB: 30.95 (27.85)             | NB: 24.39 (21.95)             | 27.67                 | 90.56               |
| ARTERY  | 4: | SB: 33.13 (29.82)             | NB: 25.66 (23.10)             | 29.40                 | 96.50               |
| ARTERY  | 5: | EB: 50.82 (45.74)             | WB: 50.82 (45.74)             | 50.82                 | 100.00              |
| <b>Report 2</b>                               |    |                               |                               |                       |                     |
| ARTERY  | 1: | EB: 55.03 (49.53)             | WB: 54.77 (49.30)             | 54.90                 | 99.77               |
| ARTERY  | 2: | EB: 2.12 ( 1.91)              | WB: 1.03 ( .93)               | 1.57                  | 4.23                |
| ARTERY  | 3: | SB: 33.33 (30.00)             | NB: 27.78 (25.00)             | 30.56                 | 100.00              |
| ARTERY  | 4: | SB: 33.13 (29.82)             | NB: 25.66 (23.10)             | 29.40                 | 96.50               |
| ARTERY  | 5: | EB: 50.82 (45.74)             | WB: 50.51 (45.46)             | 50.67                 | 99.69               |
| <b>Report 3</b>                               |    |                               |                               |                       |                     |
| 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              |
|   |    |                               |                               | <b>Report<br/>1</b>   | <b>Report<br/>2</b> |
|   |    |                               |                               |                       | <b>Report<br/>3</b> |
| AVERAGE NETWORK EFFICIENCY (percent)          |    |                               |                               | 32.90                 | 33.42               |
| AVERAGE DIRECTIONAL BANDWIDTH (sec)           |    |                               |                               | 29.61                 | 30.08               |
| NETWORK-WIDE CYCLE LENGTH (sec)               |    |                               |                               | 90.00                 | 90.00               |
| NETWORK-WIDE DELAY (veh-hrs/hr)               |    |                               |                               | 163.10                | 162.32              |
| NETWORK-WIDE FUEL CONSUMPTION<br>(gallons/hr) |    |                               |                               | 1330.22               | 1329.65             |
| NETWORK-WIDE VOC EMISSIONS (kg/hr)            |    |                               |                               | 17.31                 | 17.17               |
| NETWORK-WIDE CO EMISSIONS (kg/hr)             |    |                               |                               | 176.77                | 175.24              |
| NETWORK-WIDE NOX EMISSIONS (kg/hr)            |    |                               |                               | 17.31                 | 17.33               |

**Figure 4-8: Comparison of Multiple Solutions.**



## PRACTICAL SESSION IV: A REAL-WORLD PROBLEM

### INTRODUCTION

In this session, we will apply PASSER IV to time traffic signals for the City of Nacogdoches, Texas. Nacogdoches is considered to be the oldest town in Texas. It has a population of 32,000, and is located in the northeast part of Texas along U.S. 59.

Data for 34 signals in Nacogdoches were collected for TxDOT by a consultant and were passed to the TTI research team by TxDOT. The objective was two-fold:

1. To use these data to illustrate the application of PASSER IV to real problems, and
2. To assist TxDOT in coordinating the signal system.

Figure 5-1 shows a map of the Nacogdoches signal system. This map also provides the signal number and link length data. The traffic data included turning movement counts for AM and PM peak hours, and color photographs of the signalized approaches. The research team used the photographs to obtain information about the number of lanes and lane assignments.

For this training course, we selected the AM peak data. We excluded four signals (17, 26, 27, and 28) on Loop 224 because they are too far from the other signals and should be run in an isolated mode. Also, since no pedestrian data were available, we did not specify any minimum green split for the phases. Three signals had geometric features that required special consideration. One could not be coded, and the other two required special coding. These intersections are shown in Figure 5-2 and will be discussed in the session. After coding these data into PASSER IV, the data file was named DOCHES.DAT.

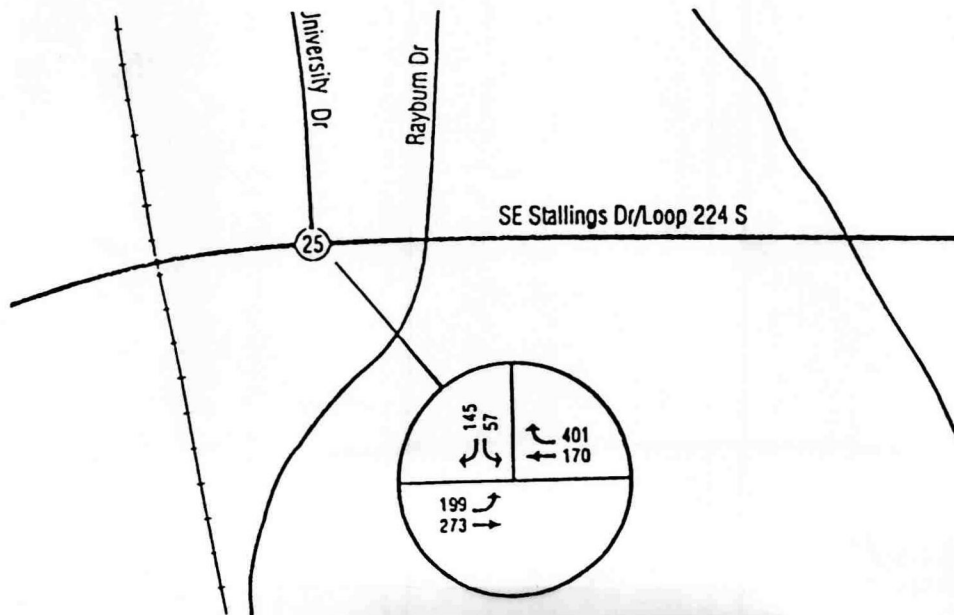
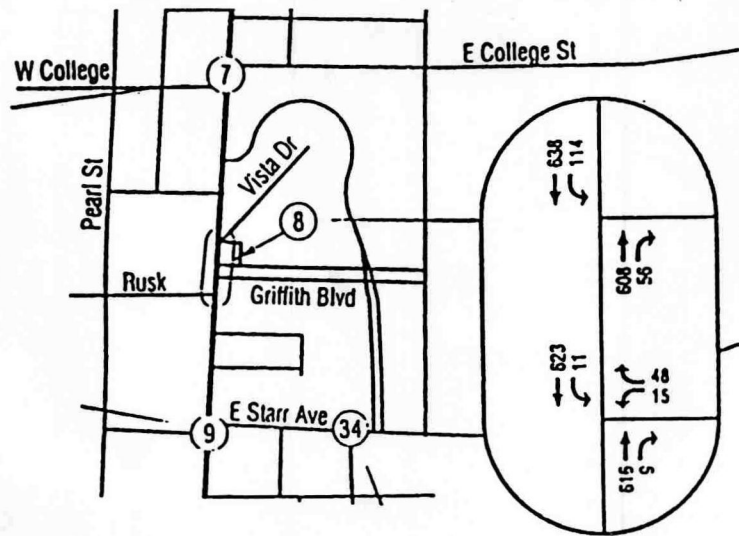
☛ Action: Load DOCHES.DAT, and view the Map.

☛ Action: View speed data.

☛ Action: Run Optimization, and view program output.

As can be seen from the output, this problem has no solution. We tried a range of cycle length from 40 seconds to 150 seconds but were not successful in obtaining a solution. We then started to systematically delete arterials from this system using the QuickEdit option. The objective was to obtain a system for which there was a feasible solution. After making several runs, it was found that a feasible solution existed when we excluded the links for East Austin Street from the system. This network consists of 29 signals and 6 arterials. We then looked at the volume-to-capacity (V/C) ratios for a range of cycle lengths. From this investigation, we determined that a system cycle length between 40 seconds and 50 seconds provided sufficient capacity for all signal approaches. Data for this system was saved as DOCHES2.DAT. A sketch of this system is shown in Figure 5-3.





**Figure 5-2: Signals Requiring Special Consideration.**

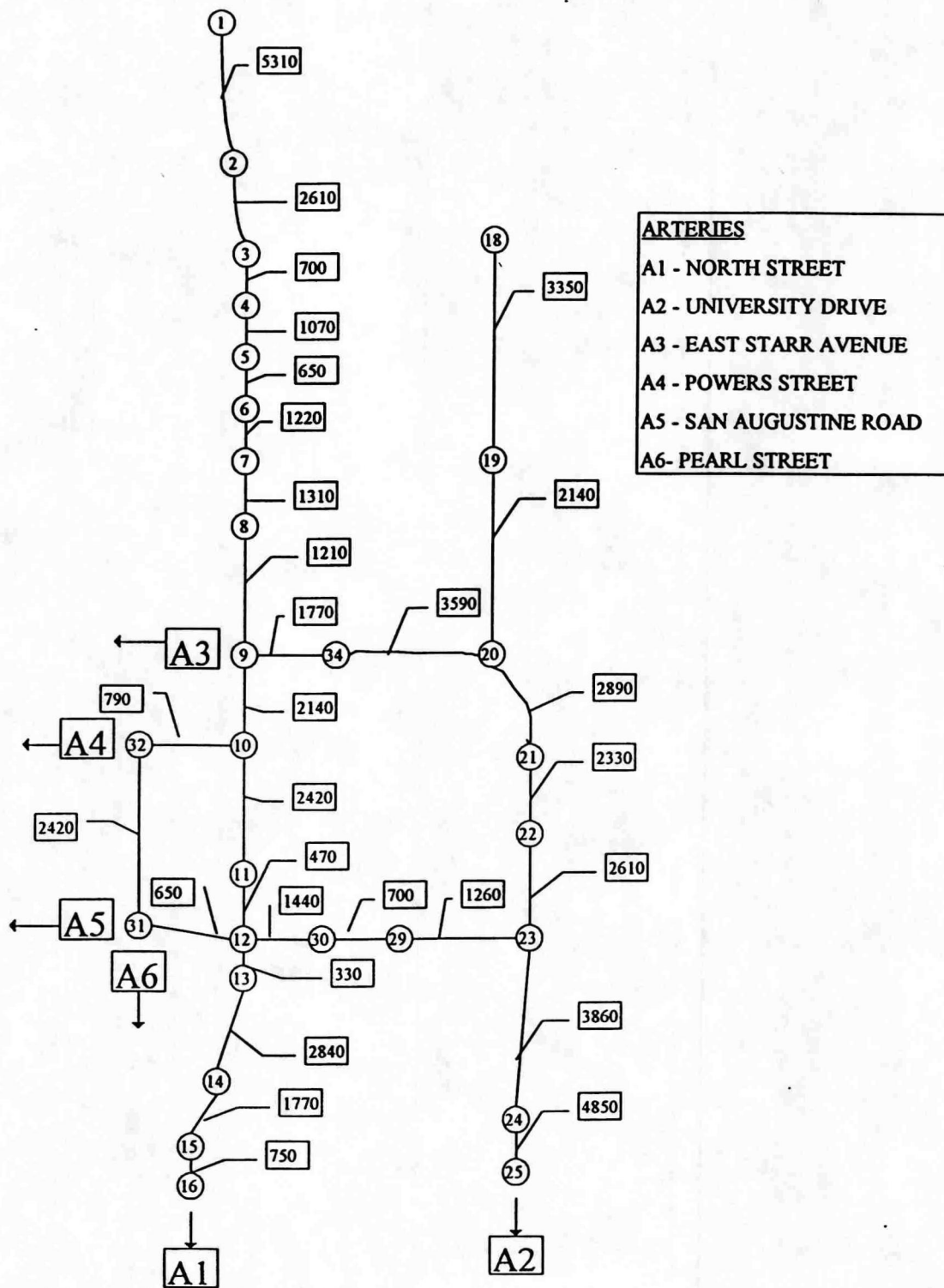


Figure 5-3: A Sketch of the Feasible Network.

- ☛ Action: Load DOCHES2.DAT.
- ☛ Action: View Map.
- ☛ Action: Run Optimization.
- ☛ Action: View Output.
  
- ☛ Action: Increase upper cycle length to 100.
- ☛ Action: Save as DOCHES3.DAT.
- ☛ Action: Run.
- ☛ Action: Look at V/C ratios.
  
- ☛ Action: Change cycle length range and cycle length minimization flag and repeat.

## **DIVIDING TO IMPROVE**

The solution obtained in the previous section was not as good as we would have liked it to be. To improve the solution, we then divided the system into three sub-systems. This was based on information provided by TxDOT. Figure 5-4 illustrates these sub-systems. The data for the three sub-systems are stored in files; DOCH-NS.DAT (north-side), DOCH-SS.DAT (south-side), and DOCH-ES.DAT (east-side). In this session, we will optimize signal timing for these three sub-systems.

- ☛ Action: Load DOCH-NS.DAT.
  
- ☛ Action: Run Optimization.
  
- ☛ Action: View Output.
  
- ☛ Action: Modify data and run Optimization.
  
- ☛ Action: View Output.
  
- ☛ Action: Repeat above steps using DOCH-SS.DAT.
  
- ☛ Action: Repeat above steps using DOCH-ES.DAT.

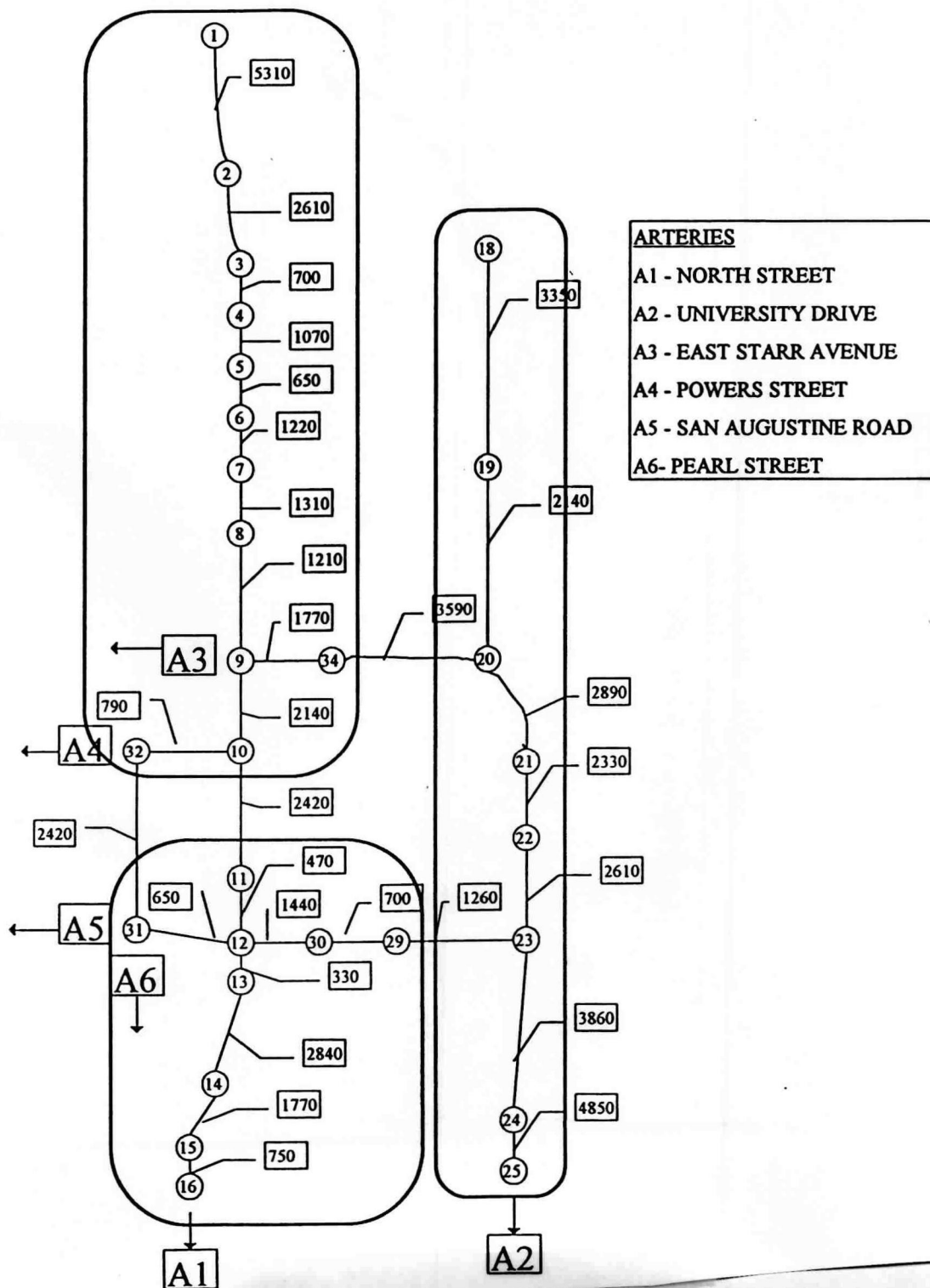


Figure 6-1: Sketch of Nacogdoches Sub-Systems.