Signal Optimization and Analysis Using PASSER V-09

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Session 0: Preliminaries

• Self Introductions
• Workshop Objectives
• Workshop Outline
**S0—Workshop Objectives**

- Learn Use of PASSER V for Analysis and Optimization of Traffic Signals:
  - Isolated TWSC Intersections
  - Isolated Signals
  - Arterials and Sub-arterials
  - Isolated Diamond Interchanges
  - Diamonds + Adjacent Signals

**S0—Workshop Outline**

- S1: Introduction to PASSER V
  - Features
  - Basic Operations
- S2: Isolated TWSC Intersections
  - Review of Theory
  - Exercise
- S3: Isolated Signals
  - Review of Theory
  - Exercise
S0—Workshop Outline (continued)

• S4: Signal Systems
  ✓ Review of Theory

• S5: Arterial Analysis
  ✓ Analyze Simple Arterials
  ✓ Review Additional Features

• S6: Diamond Interchange Analysis
  ✓ Additional Discussion
  ✓ Exercise

S0—Workshop Outline (continued)

• S7: Diamond and Adjacent Signals
  ✓ Coordinating Diamond with Adjacent Signals

• S8: Workshop Conclusion
  ✓ Question/Answer Session
  ✓ Workshop Survey
Session 1: Introduction to PASSER V

- Background
- Features
- Input Data Requirements
- User Interface

S1–PASSER V Background

- Funded by TxDOT and TTI
- Applications
  - Isolated Signals (Building Blocks)
  - Isolated TWSC Intersections
  - Signalized Arterials
  - Isolated Diamond Interchanges
  - Diamond + Adjacent Signals
**S1—PASSE R V Features**

- Graphic User Interface
  - Multiple Document Architecture
- Mesoscopic Delay/Traffic Model
- Can Coordinate Signals to Provide
  - Maximum Progression
  - Minimum Delay
- Graphic Time-Space Diagram

**S1—Using PASSE R V**

- Draw the Facility
- Select Intersection or Link
- Enter Corresponding Data
- View Signal MOEs
- Analyze/Optimize Signal Systems
  - Select and Run Tool
  - View/Print Results
**S1 – Tools in PASSER V**

- PASSER II Optimizer
- PASSER III Optimizer
- GA-Based Optimizer
- Time-Space Diagram Generator
- Volume Analysis
- Delay Analysis

**S1 – PASSER V Limitations**

- Coordination Requires Same Cycle Length at All Signals
  - No Double-Cycling or Conditional Service
- Cannot Handle Following Cases
  - One-Step Network Optimization
  - All-way Stop-controlled Intersections
Session 2: Isolated TWSC Intersections

- Input Data Needs
- Overview of Theory
- Isolated Intersection Exercise

S2–PASER V Data Needs

- Turning Movement Counts (TMC)
  - Collect 15-Minute Data and Calculate PHF
  - AM, PM, and Off-Peak
  - Collect Vehicle Mix Information
- Intersection Configurations
  - Number of Lanes, Lane Use, Lane Widths, Turn Bays and Lengths, Median Type, etc.
- Can Apply Growth Rates to Older Counts as Long as Traffic Patterns Haven’t Changed
**S2—Exercise**

- **Transportation Operations Group**

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**S2—Exercise** *(User Guide, p. 91)*

- **Texas Transportation Institute**

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S2–Gap Acceptance

- Movement
  - Ranks
- Process
  - Observe Headways
  - Accept Gap

S2–Channelized Rights

Or
S2—Two-Stage Process

Enter Storage Capacity

S2—Two-Stage Process (continued)

Enter Storage Capacity
**S2—Flared Approaches**

Specify How Many

**S2—Model Parameters**

- Critical Headway
- Follow-up Time
Session 3: Isolated Signals

- Overview of Theory
- PASSER V Input Data Needs
- Input Data Considerations
- Signal Exercise

S3 – PASSER V Data Needs

- Turning Movement Counts (TMC)
  - Collect 15-Minute Data and Calculate PHF
  - AM, PM, and Off-Peak
  - Collect Vehicle Mix Information
- Can Apply Growth Rates to Older Counts as Long as Traffic Patterns Haven’t Changed
S3—PASSE V Data Needs
(continued)

- Number of Lanes
- Lane Use
- Lane Widths
- Turn Bays and Lengths

S3—Input Considerations

- Left-turn Treatment
  - Number of Opposing Lanes
  - Overlapping Turning Paths (may need to split phase)
  - Type of Signal Heads (3, 4, or 5 Section)
- Pretimed, Semi-actuated, or Fully Actuated
- Priority or Preemption
**S3—Performance Data**

- Delay, Stops, Queue Information for Existing Conditions
- Collection Can Be Costly

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**S3—NEMA Phase Numbering**

- **Main Street Lead-Lag, Cross Street “Split Phased”**
- **NEMA Dual-Ring Phasing (leading lefts, no overlap)**
**S3–Cycle Length vs. Delay and Capacity**

- **Capacity**
- **Critical Cycle Length, C_c**
- **Minimum-Delay Cycle Length, C_m**

**S3–Cycle Length vs. Delay and Stops**

- **Queue**
- **Delay/Capacity**
- **Cycle Length**

Transportation Operations Group
**S3–Cycle Length vs. Delay**

- Select Best Timings
  - Cycle
  - Splits (or max, min, gap setting)
  - Clearance Intervals
- To Provide
  - Safe
  - Efficient Operation
**S3—Safety Issues**

- **Space Conflicts inside Intersection**
  - Use of Split Phasing
- **Minimum Greens**
  - Based on Driver Expectancy
- **Vehicle Clearance Intervals**
- **Pedestrian Requirements**
- **Yellow Trap**

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**S3—Clearance Intervals**

**Proper Settings Avoid a “Dilemma Zone”**

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Yellow Change (sec) (level grade)</th>
<th>Red Clearance (sec) (60' wide crossing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>2.84</td>
<td>2.18</td>
</tr>
<tr>
<td>35</td>
<td>3.57</td>
<td>1.55</td>
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<tr>
<td>45</td>
<td>4.31</td>
<td>1.21</td>
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<tr>
<td>55</td>
<td>5.04</td>
<td>0.99</td>
</tr>
<tr>
<td>65</td>
<td>5.78</td>
<td>0.84</td>
</tr>
</tbody>
</table>
**S3—Pedestrians**

\[ G_p = (4 \text{ to } 7 \text{ seconds}) + \frac{\text{Distance}}{W} \]

<table>
<thead>
<tr>
<th>Pedestrians</th>
<th>Minimum Pedestrian Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;WALK&quot;</td>
<td>Flashing &quot;DON'T WALK&quot;</td>
</tr>
<tr>
<td>4 to 7</td>
<td>Distance / W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicles</th>
<th>Minimum Vehicle Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow +</td>
<td>All Red Clearance</td>
</tr>
<tr>
<td>Min. Green</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signal Timing</th>
<th>Vehicular Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;WALK&quot;</td>
<td>Flashing &quot;DON'T WALK&quot;</td>
</tr>
<tr>
<td>(Minimum Pedestrian Time Controls)</td>
<td></td>
</tr>
</tbody>
</table>

Location of yellow + all red depends on policy as to allowing pedestrian flashing "DON'T WALK" to occur simultaneously with vehicular clearance.

**S3—Best Isolated Operation**

- **What is Good Operation?**
  - Minimum Delay
  - Shortest Queues per Cycle
  - Minimum Stops
  - Compromised Combination

- **User Decides Based on Situation**
  - Approach Speeds
  - Traffic Counts
  - Driver Perception
**S3–Isolated Signal Exercise**

- Draw an Isolated Signal
- Enter Data
- Analyze

**S3–Intersection Data** (User Guide, p. 91)

S.W. Military at S. Presa, San Antonio, Texas

- AM L 13 T 52 R 74 Truck% 2
- PM 19 68 150 1

- AM L 24 T 386 R 16 Truck% 3
- PM 44 635 21 1

Bay is 91' long

Bay is 153' long

Bay is 126' long
**S3–Data Entry**

- Draw Links
- Define Lanes
- Enter PM-peak Volumes
  - i.e., 149, 676, and 147 for EB
- Select Movement Type
  - EB and WB Prot (why?)
  - NB and SB Prot/Perm

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**S3–Data Entry (continued)**

- Adjust Right-turn Volumes for RTOR
- Overlap (Yes for Lefts)
- Min Splits
  - Peds if No Buttons (Assumed)
  - EB, WB, NB, SB: 23, 23, 29, 29
  - Clearance Times
**S3—Data Entry (continued)**

- Adjustments to Flows
- Trucks
- Ideal Saturation Flow
- Click Update Button

**S3—Analysis/Results**

- Delay vs. Cycle Analysis
- Controller: Ring-Barrier Display
- MOEs
Session 4: Signal Systems

• Overview:
  ✓ Engineering Theory
  ✓ Analysis Tools

S4–Flow Stability between Adjacent Systems

Min. Acceptable System Cycle Length

Delay

Cycle Length

Signal 1: Lowest v/c Ratio
Signal 2: Medium v/c Ratio
Signal 3: Highest v/c Ratio
S4—Signal Offset and Flow between Adjacent Signals

S4—Flow vs. Bands
S4—Effects of Changes in Offset

S4—Cannot Get Two-way Bands? Change Phasing!
S4—Changing Phasing Can Improve 2-way Progression

S4—Yellow Trap

Demonstration of Lead-Lag “YELLOW TRAP”
S4—Yellow Trap (continued)

Southbound

Dallas Phasing

Northbound

S4—Yellow Trap (continued)

Southbound

Arlington Phasing

Northbound
S4 – Timing Adjacent Signals

• Objectives of Coordination
  ✓ Provide/Maintain Safety
  ✓ Maintain Stable Flow
  ✓ Minimize Systemwide Delay
  ✓ Minimize Queues and Spillback
  ✓ Maximize System Throughput
  ✓ Minimize Number of Stops
  ✓ Maximize Arterial Progression

S4 – Types of Models

• Traffic Simulation Model
  ✓ Evaluates a Specified Scenario
  ✓ Generates Performance Measures

• Optimization Model
  ✓ Systematically Generates Scenarios
  ✓ Evaluates Using Simulation
  ✓ Selects the Best Scenario
  ✓ Usually Applicable to Traffic Signals
**S4—Simulation Models**

- **Microscopic**
  - Keeps Track of Each Vehicle
  - Time Consuming

- **Mesoscopic**
  - Analyzes Flow Profiles
  - Faster Calculations

- **Macroscopic**
  - Analyzes Platoons
  - Fastest Calculations

**S4—Simulation Models (continued)**

- **Stochastic**

- **Deterministic**

- **Microscopic**
  - Keeps Track of Each Vehicle
  - Time Consuming

- **Mesoscopic**
  - Analyzes Flow Profiles
  - Faster Calculations

- **Macroscopic**
  - Analyzes Platoons
  - Fastest Calculations
**S4—Simulation Accuracy**

- **Realistic Queues**
  - Microscopic: CORSIM, Vissim, SimTraffic
  - Mesoscopic: new T7F, PASSER V, Synchro

- **Upward Queue Stack**
  - Mesoscopic: old T7F, S5 and P3
  - Macroscopic: P2, P4

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**S4—Spillback & Starvation**
S4—Blocking and Starvation

(continued)
**S4—Starvation May Not Be Bad (Unused Capacity)**

- Maximize Arterial Progression
- Minimize Systemwide Delay
- Minimize Stops
- Minimize Queues
- Maximize Throughput
- Minimize Blocking and Spillback
**S4—Magnitude of Problem**

Fixed Cycle = 100 Sec

1: 2-Phase Signals

1. 100 Plans

2. Depends
   - 200, or
   - 10,000 Plans

3. 200 x 64 = 12,800 Plans

**S4—Optimization Methods**

- Exhaustive Search
- Smart Search Techniques
  - Hill-climbing
  - Heuristic
  - Mathematical Programming
  - Genetic Algorithms
- Most Signal-Timing Programs Use a Combination
**S4—Optimization Tool Types**

- **Delay-Based**
  - Minimizes Delay (+Qs and Stops)
  - Evaluates/Simulates Each Plan
  - Examples:
    - TRANSYT 7F: Exhaustive, Hill-climbing, GA
    - Synchro: Exhaustive + Heuristic Search
    - PASSER III: Exhaustive Search
    - PASSER V: Exhaustive, GA

(continued)

- **Bandwidth-Based**
  - Maximizes Arterial Progression
  - Simple Objective Function
  - Simulates Traffic after Optimization
  - Examples:
    - PASSER II: Exhaustive and Heuristic
    - PASSER IV: Mathematical Programming
    - PASSER V: Exhaustive, Heuristic, GA
**S4—PASSE R V Data Needs**

- Signal Spacing
- Link Speeds
- Types of Link

**S4—Input Performance Data**

- Speed, Travel Time, or Delay Information for Existing Conditions
- May Need to Measure Speed for Use in PASSER V
- Can Be Used to Calibrate or Validate Your Base Model
- Collection Can Be Costly
Session 5: Arterial Analysis

- Arterial Exercise 1
  - Load and Review Data
  - Apply Various Tools
  - Review/Interpret Output

- Arterial Exercises 2 and 3
  - TWSC Intersections
  - Sub-nets
  - Phasing Options
  - Bandwidth-constrained Delay Minimization
  - Adjusting Bands

S5—Arterial Exercise 1 (User Guide, p. 130)
S.W. Military Drive, San Antonio, Texas

*Assume all lanes at Somerset are 12' wide*
**S5—Performance Measures**

- **Cycle Length, C**
- **Shortest green time among all the signals on A-direction, \( G_{\text{min}}(A) \)**
- **Bandwidth on A-direction, \( \text{Band}(A) \)**
- **Shortest green time among all the signals on B-direction, \( G_{\text{min}}(B) \)**
- **Bandwidth on B-direction, \( \text{Band}(B) \)**

\[
\text{Total Band} = \text{Band}(A) + \text{Band}(B)
\]

\[
\text{Efficiency} = \frac{\text{Total Band}}{2 \times C} \times 100
\]

\[
\text{Attainability} = \frac{\text{Total Band}}{G_{\text{min}}(A) + G_{\text{min}}(B)} \times 100
\]

**S5—NTCIP Coord Phase**

```
DIAL 1 SPLIT 1 PHASE PARAMETERS
PHASE......1..2..3..4...5...6..7..8
TIME 0 0 0 0 0 0 0 0
MODE: 0-ACTUATED 1-COORD PH 2-MIN REC
       3-MAX REC 4-PED REC 5-MX+F REC
       6-PH OMIT 7-DUAL COORD PHASE
A-UP B-DN C-LT D-RT E-ENTER F-PRIOR MENU
```

```
SPL-32 Ø...1...2...3...4...5...6...7...8 ->
Time 25 25 25 25 25 25 25
Code-Ø X . . . .
Mode NON MAX NON NON NON MAX NON NON
```
**S5–NTCIP Coord Phase**

(continued)

Coordinate Phase: 2

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<thead>
<tr>
<th>φ1</th>
<th>φ2</th>
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<tbody>
<tr>
<td>←</td>
<td>→</td>
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</table>

<table>
<thead>
<tr>
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<th>φ6</th>
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<tbody>
<tr>
<td>↑</td>
<td>←</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>φ2</th>
<th>φ1</th>
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<tbody>
<tr>
<td>→</td>
<td>←</td>
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<table>
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<th>φ5</th>
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<tbody>
<tr>
<td>←</td>
<td>↑</td>
</tr>
</tbody>
</table>

**Offset Adjustments**

- **Lead-Lead Example**

  Offset 10 Sec

  Phase 2

- **Lag-Lead Example**

  Offset 10 Sec

  Phase 2
**S5—Programming Sequences**

(continued)

**EPAC SEQUENCE 1 (ALT SEQ 0)**

**PHASE SEQUENCE BY RING**

<table>
<thead>
<tr>
<th>PHASE</th>
<th>01-02</th>
<th>03-04</th>
<th>00-00</th>
<th>00-00</th>
<th>00-00</th>
<th>00-00</th>
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<tbody>
<tr>
<td>R1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A-UP</td>
<td>B-DN</td>
<td>E-EDIT</td>
<td>F-PRIOR</td>
<td>MENU</td>
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</table>
**Example Phase Sequences**

<table>
<thead>
<tr>
<th>Sequence Name</th>
<th>Ring</th>
<th>Phase Order</th>
<th>Sequence # Eagle/Naztec</th>
</tr>
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<tbody>
<tr>
<td>Lead-Lead</td>
<td>1</td>
<td>1 2 3 4</td>
<td>0/1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5 6 7 8</td>
<td></td>
</tr>
<tr>
<td>Lag-Lead</td>
<td>1</td>
<td>1 2 3 4</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6 5 7 8</td>
<td></td>
</tr>
<tr>
<td>Lead-Lag</td>
<td>1</td>
<td>2 1 3 4</td>
<td>2/3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5 6 7 8</td>
<td></td>
</tr>
<tr>
<td>Lag-Lag</td>
<td>1</td>
<td>2 1 3 4</td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6 5 7 8</td>
<td></td>
</tr>
</tbody>
</table>

**How Genetic Algorithm (GA) Works**

- Randomly Generate Population
- Perform Reproduction Operation
  - Select Pairs/Parents and Generate Offspring
    - ![Parents](#) ![Offspring](#)
- Evaluate Each Using Simulation
  - Note Population Has Doubled
**S5—How GA Works (continued)**

- Keep Best Half of New Population

  ![Parents and Offspring](image)

- Perform Mutation Operation

  ![Mutation Operation](image)

- Stop If
  - No Improvement Possible or Maximum Generations Reached
  - Report the Best Plan

- Else
  - Repeat Process
S5–Arterial Exercise 2

S5–More Theory

• Handling of TWSC Intersections on Arterial
  ✓ Upstream Signals
    » Platoon Dispersion
  ✓ Handling in Various Tools
    » PASSER II
    » Other Tools (Except P3)
S5–Arterial Exercise 3

SH 71, Bastrop, Texas

S5–Bandwidth vs. Efficiency

Transportation Operations Group
S5—Delay and Attainability

S5—Tradeoffs in Performance
Session 6: Diamond Interchange Analysis

- Background and Operational Issues
- Diamond Exercise
  - Create Interchange
  - Apply Optimization Tools and View Output
    - PASSER III
    - GA-Based Optimizer
- Apply Other Tools
  - Volume Analysis
  - Time-Space Diagram
  - Delay Analysis

S6—Background on Diamonds

- Two Closely Spaced Intersections
- Flow Characteristics Very Different from Arterials
  - Significant Turning Traffic
- Types
  - Conventional (More than 800 ft)
  - Compressed (400-800 ft)
  - Tight (Less than 400 ft)
**S6—Background on Diamonds**
(continued)

- Often Experience Operational Problems
- Capacity Dependent on
  - Splits at Both Intersections
  - Queuing and Spillback
- TxDOT/Texas Diamond Controller
  - Basic Three-Phase
  - TTI Four-Phase
  - Separate Intersection Mode

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**S6—NEMA Phase Numbering**

\[ \phi_3 \rightarrow \phi_4 \]

Crossing Arterial

\[ \phi_2 \leftrightarrow \phi_1 \rightarrow \phi_5 \rightarrow \phi_6 \]

Overlap A (\( \phi_1 + \phi_2 \))

Left Side Frontage/Ramp

\[ \phi_8 \leftrightarrow \phi_7 \]

\( \phi_X \) - NEMA Phase

Right Side Frontage/Ramp
**S6—Three-Phase Operation**

- Transportation Operations Group

**S6—Four-Phase Operation**

- Lead-Lead Phasing
- Phase Times and Offset Calculated Simultaneously
- Needs Longer Cycle
**S6—Other Options**

- Separate Intersection Control under Diamond Mode
  - Restricted to Lead-Lead Phasing
  - Can Provide Ring-lag/Offset
- User Programmed Mode
  - Difficult Programming
  - Flexibility of Operation
- Use Two Controllers

**S6—Phasing Selection Guidelines**

- Conventional Diamonds
  - Three-Phase
  - Four-Phase Not Recommended
- Compressed Diamonds
  - Three-Phase with Short Cycle
  - Four-Phase
- Tight Diamonds
  - Four-Phase
  - Three-Phase for Light Traffic
**S6 – Diamond Exercise** (User Guide, p. 119)

**S6 – Data Entry/Analysis**

- Draw Links/Define Interchange
- Load Data
- Select Tool and Analyze
- Review Results
S6—More Tools in PASSER V

- Volume Analysis
- Time-Space Diagram
- Delay Analysis

Session 7: Diamond and Adjacent Signals

- Exercise Using Existing Data
- Apply Various Tools
- Review Output
**Session 8: Workshop Conclusion**

- **Additional Topics and QA Session**
  - Any Features Not Covered
  - Networks
- **Survey**
  - Tell Us How We Did
  - Feedback about PASSER V