Signal Optimization and Analysis Using PASSER V

Training Workshop

Nadeem Chaudhary, P.E.
Steven Venglar, P.E.
Chi-Leung Chu

Sponsored by TxDOT under Project 5-4020

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 Signals
  - Isolated Diamond Interchanges
  - Diamonds + Adjacent Signals
  - Arterials and Sub-arterials

**S0—Workshop Outline**

- **S1:** Introduction to PASSER V
  - Features
  - Input Data Requirements
- **S2:** Isolated Signals
  - Review of Theory
  - Isolated Signal Exercise
- **S3:** Signal Systems
  - Review of Theory
**S0—Workshop Outline (continued)**

- S4: Diamond Interchange Exercise
  - Additional Discussion
- S5: Arterial Exercises
  - Analyze Simple Arterials
  - Review Additional Features
- S6: Diamond + Arterial Exercise
  - Coordinating Diamond with Adjacent Signals

---

**S0—Workshop Outline (continued)**

- S7: Workshop Conclusion
  - Multi-Arterial Network Case Studies
  - 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)
  - Signalized Arterials
  - Isolated Diamond Interchanges
  - Diamond + Adjacent Signals
**S1—PASSER V Features**

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

**S1—Using PASSER 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
  - Network Optimization
  - Un-Signalized Intersections
**Session 2: Isolated Signals**

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

---

**S2–Cycle vs. Delay and Capacity**

- Critical Cycle Length, $C_c$
- Minimum-Delay Cycle Length, $C_m$
S2—Cycle vs. Delay and Stops

S2—Cycle Length vs. Delay
**S2—Timing Isolated Signals**

- Select Best Timings
  - Cycle
  - Splits (or max, min, gap setting)
  - Clearance Intervals

- To provide
  - Safe
  - Efficient Operation

**S2—Safety Issues**

- Space Conflicts Inside Intersection
  - Use of Split Phasing

- Minimum Greens
  - Based on Driver Expectancy

- Vehicle Clearance Intervals

- Pedestrian Requirements

- Yellow Trap
S2—Clearance Intervals

- Proper Settings Avoid a “Dilemma Zone”

<table>
<thead>
<tr>
<th>Speed mph (kph)</th>
<th>Yellow Change sec (level grade)</th>
<th>Red Clearance sec (60’ wide crossing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 (40)</td>
<td>2.84</td>
<td>2.18</td>
</tr>
<tr>
<td>35 (56)</td>
<td>3.57</td>
<td>1.55</td>
</tr>
<tr>
<td>45 (72)</td>
<td>4.31</td>
<td>1.21</td>
</tr>
<tr>
<td>55 (88)</td>
<td>5.04</td>
<td>0.99</td>
</tr>
<tr>
<td>65 (104)</td>
<td>5.78</td>
<td>0.84</td>
</tr>
</tbody>
</table>

S2—Pedestrians

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

Location of yellow + all red depends on policy as to allowing pedestrian flashing “DON’T WALK” to occur simultaneously with vehicular clearance.
**S2—Yellow Trap**

Demonstration of Lead-Lag “YELLOW TRAP”

**S2—Yellow Trap (continued)**

Dallas Phasing
S2—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

S2—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
S2–PASSER V Data Needs (continued)

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

S2–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
**S2—Performance Data**

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

**S2—Isolated Signal Exercise**

- Draw an Isolated Signal
- Enter Data
- Analyze
**S2–NEMA Phase Numbering**

NEMA Dual-Ring Phasing
(leading lefts, no overlap)

Main Street Lead-Lag,
Cross Street “Split Phased”

---

**S2–Intersection Data**

<table>
<thead>
<tr>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>13</td>
</tr>
<tr>
<td>T</td>
<td>52</td>
</tr>
<tr>
<td>R</td>
<td>74</td>
</tr>
<tr>
<td>Truck%</td>
<td>2</td>
</tr>
</tbody>
</table>

Bay is 91' long

<table>
<thead>
<tr>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>24</td>
</tr>
<tr>
<td>T</td>
<td>386</td>
</tr>
<tr>
<td>R</td>
<td>16</td>
</tr>
<tr>
<td>Truck%</td>
<td>3</td>
</tr>
</tbody>
</table>

Bay is 153' long

<table>
<thead>
<tr>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>113</td>
</tr>
<tr>
<td>T</td>
<td>85</td>
</tr>
<tr>
<td>R</td>
<td>45</td>
</tr>
<tr>
<td>Truck%</td>
<td>8</td>
</tr>
</tbody>
</table>

Bay is 126' long

S. Presa

S.W. Military

N

---
S2–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

S2–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
**S2—Data Entry** (continued)

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

**S2—Analysis/Results**

- Delay vs. Cycle Analysis
- Controller: Ring-Barrier Display
- MOEs
Session 3: Signal Systems

Overview:
✓ Engineering Theory
✓ Analysis Tools

S3—Flow Stability Between Adjacent Systems

Min. Acceptable System Cycle Length

Delay

Cycle Length

Signal 3: Highest v/c Ratio
Signal 2
Signal 1: Lowest v/c Ratio
**S3—Signal Offset and Flow Between Adjacent Signals**

**S3—Flow vs. Bands**
**S3—Effects of Changes in Offset**

Offset +

**S3—Cannot Get Two-way Bands? Change Phasing!**

Offset -
S3—Changing Phasing Can Improve 2-way Progression

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
S3—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

S3—Simulation Models

- Microscopic
  - Keeps Track of Each Vehicle
  - Time Consuming

- Mesoscopic
  - Analyzes Flow Profiles
  - Faster Calculations

- Macroscopic
  - Analyzes Platoons
  - Fastest Calculations
S3—Simulation Models (continued)

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

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

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

- **Stochastic**

- **Deterministic**

S3—Simulation Accuracy

- **Realistic Queues**
  - Microscopic: CORSIM, Vissim, SimTraffic
  - Mesoscopic: new T7F, PASSER V, Synchro 6

- **Upward Queue Stack**
  - Mesoscopic: old T7F, S5 and P3
  - Macroscopic: P2, P4
**S3—Spillback & Starvation**

**S3—Blocking and Starvation**
**S3—Blocking and Starvation (continued)**

**S3—Starvation May Not Be Bad (Unused Capacity)**
**S3—Optimization Criteria**

- Maximize Arterial Progression
- Minimize Systemwide Delay
- Minimize Stops
- Minimize Queues
- Maximize Throughput
- Minimize Blocking and Spillback

**S3—Optimization Methods**

- Exhaustive Search
- Smart Search Techniques
  - Hill-climbing
  - Heuristic
  - Mathematical Programming
  - Genetic Algorithms
- Most Signal-Timing Programs Use a Combination
**S3—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
**S3–PASSER V Data Needs**

- Signal Spacing
- Link Speeds
- Types of Link

![Diagram of intersection spacing](image)

**S3–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 4: 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

S4—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)
**S4—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

**S4—NEMA Phase Numbering**

- \( \phi_3 \)
- \( \phi_4 \)
- Crossing Arterial
  - Overlap A (\( \phi_1 + \phi_2 \))
- \( \phi_2 \)
- \( \phi_1 \)
- Overlap B (\( \phi_5 + \phi_6 \))
- \( \phi_5 \)
- \( \phi_6 \)
- \( \phi_8 \)
- Left Side Frontage/Ramp
- Right Side Frontage/Ramp
- \( \phi_7 \)
- \( \phi_X - NEMA \) Phase
**S4—Three-Phase Operation**

- \[ \text{Fixed Interval Transition} \]
- \[ \text{Lead-Lead Phasing} \]
- \[ \text{Phase Times and Offset Calculated Simultaneously} \]
- \[ \text{Needs Larger Cycle} \]

**S4—Four-Phase Operation**

- \[ \text{Fixed Interval Transition} \]
- \[ \text{Left Hand Side Exterior Served} \]
- \[ \text{Right Hand Side Exterior Served} \]
- \[ \text{Fixed Interval Transition} \]
**S4—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

**S4—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
S4–Diamond Exercise

- SH 6 (East Bypass)
- Harvey Rd.
- Protected + Permitted
- Speed = 40 mph
- Bay Length = 300 ft
- All lanes 12 ft

S4–Data Entry/Analysis

- Draw Links/Define Interchange
- Load Data
- Select Tool and Analyze
- Review Results
**S4—How GA Works**

- Randomly Generate Population
- Perform Reproduction Operation
  - Select Pairs/Parents, and Generate Offspring
- Evaluate Each Using Simulation
  - Note Population Has Doubled

**S4—How GA Works (continued)**

- Keep Best Half of New Population
- Perform Mutation Operation

Next Generation
**S4—How GA Works (continued)**

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

**S4—More Tools in PASSER V**

- Volume Analysis
- Time-Space Diagram
- Delay Analysis
Session 5: Arterial Analysis

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

- Arterial Exercise 2
  - Review Additional Features
    - Creating and Working with Sub-nets
    - Phasing Options
    - Bandwidth-constrained Delay Minimization
    - Adjusting Bands

S5 - Arterial Exercise 1

*Assume all lanes at Somerset are 12' wide

New Laredo Highway
Bay is 145' long

SW Military
Bay is 140' long

Transportation Operations Group
S5–Arterial Exercise 2

S5–Band vs. Efficiency

- Total Band (sec)
- Total Efficiency (%)

Cycle Length

Band Width

Efficiency

90
80
70
60
50
45
40
35
30
25
20
15
10
5
0

0 10 20 30 40 50 60 70 80 90 100 110 120
S5–Delay and Attainability

S5–Tradeoffs in Performance
Session 6: Diamond and Adjacent Signals

- Exercise Using Existing Data
- Apply Various Tools
- Review Output

S6–SH 195 Data
Session 7: Workshop Conclusion

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

TTI is Here to Help

- Nadeem Chaudhary
  - n-chaudhary@tamu.edu
  - (979) 845-9890
- Steve Venglar
  - s-venglar@tamu.edu
  - (210) 979-9411
- Chi-Leung Chu
  - clchu@tamu.edu
  - (979) 845-8408