Construction Analysis for Pavement Rehabilitation Strategies

CA4PRS Peer–Exchange Workshop

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AGENDA

CA4PRS Introduction

Schedule Module

Traffic Module

Cost Module
Challenge

AASHTO President (MO-DOT)

Transconomy:
- No Transportation => No Economy

AASHTO Report: “Unlocking Freight”

Demand-Supply unbalance (’80-’06)
- 150% more traffic vs 15% highway capacity up
- $63 billion of yearly user delay cost

Freight: Trucks carry 74% of loads
- In 10 years: 1.8 mil more trucks
- In 20 years: 50% trucks than NOW
Highway Infrastructure Renewal & Impacts

• Aging highway infrastructure needs renewal
  – State DOT 4-R projects; Renewal research-SHRP2
• How to minimize the Impacts of WZ lane closures?
  – Quantify impacts to motorists and local businesses
  – Work-zone mobility and safety
  – State-wide process & project-level procedure: TMP
• Integration approach: analysis tools to balance
  – Tolerable traffic delays in WZ
  – Faster construction delivery
  – Longer lasting pavements
  – Affordable agency budget
CA4PRS Software Development and Nationwide Implementation

- CA4PRS software development
  - Pooled-fund (CA, MN, TX, WA): UCB-FHWA-Caltrans
  - Help develop optimum construction-staging plans and TMP
  - Multi-discipline collaboration and teamwork building

- FHWA Outreach
  - 2009 Market-ready Innovation and Technology Product
  - Arranged Free-group License for all 50 State DOTs
  - Trainings: 1,000 Engineers in 20 states, 10 universities

- AASHTO Promotion
  - Exhibit, Presentation: AASHTO Committee, Conference

- 2007 International Road Federation Award
Hands-on Training Workshops:
Caltrans + 20 DOTs => 1,100 engineers
### CA4PRS Implementation Projects

#### CA DOT (Caltrans) Projects

<table>
<thead>
<tr>
<th>No</th>
<th>Route</th>
<th>Location</th>
<th>Type</th>
<th>Project Cost</th>
<th>Savings*</th>
<th>Distance</th>
<th>Year</th>
<th>Status</th>
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<tbody>
<tr>
<td>1</td>
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<td>$16M</td>
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<td>-</td>
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<td>24 miles</td>
<td>2010</td>
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<tr>
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<td>Stockton, D10</td>
<td>Rehab</td>
<td>$45M</td>
<td>-</td>
<td>3 mile</td>
<td>2012</td>
<td>Adopted</td>
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#### Other State DOT Projects

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<th>No</th>
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<th>Type</th>
<th>Project Cost</th>
<th>Savings*</th>
<th>Distance</th>
<th>Year</th>
<th>Status</th>
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<tr>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>2010</td>
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</tbody>
</table>
CA4PRS Analysis Process

Alternatives
“What-If” Scenarios

Module 1

SCHEDULE Constructable?

No

Yes

Module 2

TRAFFIC Tolerable?

No

Yes

Module 3

COST Budget?

No

Yes

TMP PS&E

Closure Numbers
Project Duration
Construction Staging

Queue & Delay
Road User Cost
Demand control

Project Cost
Agency, Traffic, Support
Life-cycle (LCCA)

Decision-Support Model
Multi-discipline Team-work
CA4PRS Comparison Alternatives

• Pavement Design Alternatives
  – Rehabilitation Strategies
    • **Rigid**: JPCP, CRCP, Precast
    • **Flexible**: Overlay, Milling-filling AC, Full-depth AC
  – Variation: Cross-section, Mix, Base type

• Work-zone Traffic Alternatives
  – Construction window: Night, Day, Weekend, Continuous
  – WZ Capacity Sensitivity: Lane width, Geometry, Trucks
  – Demand Sensitivity: No-shows and Detours

• Constructability and Logistics Alternatives
  – Construction trucks: Loading & discharging cycle
  – Construction sequence: Site access
  – Constructability: Demolition methods, and Mix types
Concrete Pavement Cross-sections

(a) Milling Filling AC
(b) Concrete Slab Replacement
(c) Concrete Slab & Base Reconstruction

CA4PRS Compares Cross-section Change Alternatives from SCHEDULE-TRAFFIC-COST
Closure <=> Access <=> Production

Full Closure for Concurrent Method

More Closure =>
Better Access =>
Faster Schedule;
Higher Delay
Closure <=> Access <=> Production
Partial Closure for Sequential Method

Closure => Limited Access => Production

Less Closure =>
Limited Access =>
Slower Schedule
Less Delay
Work-zone Traffic Delay Analysis
Demand-Capacity (Macro-model): HCM 2000

- Road user cost (RUC)
  - Delay cost: Queue-delay (traveler's time value)
  - Vehicle operation costs: maintenance, fuel, emission, crash
  - Detour cost: circuity or diversion (better in network analysis)
CA4PRS WZ Traffic Module
Inputs & Outputs (HCM Model)

• Basic Input Data
  – Closure schedule inputs: from SCHEDULE module
  – 24 hourly traffic volumes
  – Lanes open (closure) schemes
  – User’s Time values (vehicle cost)
  – WZ Capacity (Sensitivity) and Demand Management

• Demand-management & Capacity-adjustment
  – Demand reduction: no-shows and detour
  – WZ capacity: Terrain, Truck, lane-width, lateral clearance

• WZ Impact Analysis Outputs
  – Max queue length and Max delay per closure
  – Total Road User Cost

• WZ Analysis Application
  – Evaluate TMPs and develop Lane closure charts
  – Contract: Incentives/Disincentive & A+B
CA4PRS Estimate

Agency (Project) Cost

- Pavement Cost: Itemized unit-price and Qty
  - Materials (PCC, HMA, RAC, Pre-cast), Base, Subbase
  - Item unit-price from Bid-database
- Non-pavement Cost: % of Construction-cost
  - Earth work cost; Drainage cost
  - Specialty (Retaining/Barrier), Storm-water (SWPPP)
- Traffic Cost
  - TMP (COZEEP, I/D) and Traffic-handling, Outreach
- Indirect Cost: % of Construction-cost
  - Minor, Mobilization, Supplemental, Contingency
  - Supporting: Agency (Plan, Design, Traffic, Construction)
- Other Optional Cost
  - Structure and ROW

=> Project Cost
Caltrans Bid Cost DB Website
http://sv08data.dot.ca.gov/contractcost
10 lane-mile of PCC Pavement were Rebuilt
TWO 8-day closures (Non-stop Construction)

I-15 Devore PCC Reconstruction Project, 2005

Saved $8M Agency Cost!
It would take 10 month of Nighttime Closures
I-15 Devore Daily Traffic Patterns
- Approximately 120,000 ADT (10% trucks)
- Weekdays Commuters + Weekend Leisure
I-15 Devore Web-Surveys
Public Perception Changes

Before-construction

- Negative: 11%
- Continuous closures, 7%
- Adding lane, 4%
- No, Cancel project, 14%
- Other

After-construction

- No, Weeknight or weekend, 64%
- No, Cancel project, 14%
- Yes, 70%

Do you support 72-h (3-weekday) Weekday closures?

Do you support future “Rapid-Rehab” projects?
CA4PRS on the Web (CD)

Construction Analysis for Pavement Rehabilitation Strategies
Caltrans "Rapid Rehab" Software

A Decision-Support Tool to Integrate Design, Construction, and Traffic for Highway Projects

Development Background

State transportation agencies are increasingly shifting their focus from constructing new highways to rehabilitating and reconstructing existing facilities. Because highway rehabilitation projects often cause congestion, safety problems, and limited access for road users, agencies face a challenge in finding economical ways to rehabilitate deteriorating roadways in metropolitan areas while keeping the traveling public as safe as possible and minimizing disruptions for local communities and surrounding businesses.

One innovation in the effort to reduce highway construction time and its impact on traffic is software called CA4PRS, Construction Analysis for Pavement Rehabilitation Strategies. CA4PRS is a schedule and traffic analysis tool that helps planners and designers select effective, economical rehabilitation strategies. Funded through an FHWA (Federal Highway Administration) pooled-fund, multistate consortium (California, Minnesota, Texas, and Washington), CA4PRS was developed by the University of California pavement Research Center (UCPRC) through the UC Berkeley Institute of Transportation Studies. FHWA formally endorsed CA4PRS as a "Priority, Market-Ready Technologies and Innovations" product in 2008 for national-wide deployment. Caltrans IT recently added CA4PRS into the standard software list for its statewide implementation.

http://www.dot.ca.gov/hq/research/roadway/ca4prs/index.htm
CA4PRS Implementation in Project Life Cycle Process

- Planning Stage (PSR/PA&ED): Scope and Priority
  - VE Analysis and Life-cycle Cost Analysis

- Design Stage: PS&E & TMP packages
  - Working-days (CPM); Construction staging plans
  - TMP Report and Lane closure charts

- Construction Stage
  - Validate contractor’s work-plans and CCO

- Upcoming Enhancement Modules
  - Currently V2.5: Schedule-Traffic-Cost for M & R
  - V3.0 Roadway Widening Module
  - V3.5 Bridge Replacement Module
  - V4.0 LCCA Interaction Module
More CA4PRS Information?

• Contacts
  – Dr. E.B. Lee: UC Berkeley-ITS
    • (510) 665-3637; eblee@berkeley.edu
  – Ken Jacoby: FHWA Office of Asset Management
    • 202-366-6503; Ken.Jacoby@dot.gov
  – Dr. Nadarajah Sivaneswaran (Siva): FHWA Turner-Fairbank
    • (202) 493-3147; n.sivaneswaran@dot.gov
  – Michael Samadian: Caltrans Research
    • (916) 324-2048; Michael_M_Samadian@dot.ca.gov
## I-15 Devore Pre-construction Analysis

**CA4PRS Schedule-Traffic-Cost Comparison**

<table>
<thead>
<tr>
<th>Construction Scenario</th>
<th>Construction Schedule</th>
<th>WZ Traffic Delay</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Closures</td>
<td>Closure Hours</td>
<td>Max. Delay (Min)</td>
</tr>
<tr>
<td>One Roadbed Continuous (24/7)</td>
<td>2</td>
<td>400</td>
<td>80</td>
</tr>
<tr>
<td>72-Hour Weekday Non-stop</td>
<td>8</td>
<td>576</td>
<td>50</td>
</tr>
<tr>
<td>55-Hour Weekend Extended</td>
<td>16</td>
<td>880</td>
<td>80</td>
</tr>
<tr>
<td>9-Hour Nighttime Closures</td>
<td>230</td>
<td>2,100</td>
<td>50</td>
</tr>
<tr>
<td>8-Hour Nighttime Closures</td>
<td>300</td>
<td>2,400</td>
<td>20</td>
</tr>
<tr>
<td>7-Hour Nighttime Closures</td>
<td>410</td>
<td>2,900</td>
<td>10</td>
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</tbody>
</table>
Constructability Inputs: **Truck-numbers for Demolition and Mix-type**
Milling (Cold-plane) Production Trend

(Aggregates: Granite)

(Aggregates: Limestone)

(Wirtzen W1900 Model)
## Roadway Elevation Change

**No-, Up-, or Down-elevation**

<table>
<thead>
<tr>
<th>AC</th>
<th>254mm (10&quot;)</th>
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<tbody>
<tr>
<td>Aggregate Base Subgrade</td>
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### No Change

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<th>0.5 hour</th>
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<tbody>
<tr>
<td>Type C</td>
<td>76 mm</td>
<td>1 hour</td>
</tr>
</tbody>
</table>

### UP (3")

<table>
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<th>OGAC</th>
<th>25 mm</th>
<th>0.5 hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type C</td>
<td>76 mm</td>
<td>1 hour</td>
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</table>

### DOWN (4")

<table>
<thead>
<tr>
<th>OGAC</th>
<th>25 mm</th>
<th>0.5 hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type C</td>
<td>76 mm</td>
<td>1 hour</td>
</tr>
</tbody>
</table>

- **Milling = 6" AC = 6"**
- **Milling = 3" AC = 6"**
- **Milling = 10" AC = 6"**
<table>
<thead>
<tr>
<th>Input Window</th>
<th>Parameters</th>
<th>Nighttime Closures</th>
<th>Extended Closures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Details</strong></td>
<td>Objective / Scope (lane-mile)</td>
<td>Sum of [\text{distance} \times \text{lane numbers} \times \text{direction}]</td>
<td>[\text{Ex: 20 lane-mile} = 5 \text{mile stretch} \times 2 \text{lanes} \times 2 \text{direction}]</td>
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<tr>
<td><strong>Activity Constraints</strong></td>
<td>Mobilization (hour)*</td>
<td>0.5 - 1.0</td>
<td>2 - 3</td>
</tr>
<tr>
<td></td>
<td>Demobilization (hour)*</td>
<td>2 - 4</td>
<td>4 - 6</td>
</tr>
<tr>
<td></td>
<td>Leg-time (hour)</td>
<td>(1 - \frac{2}{(\text{Sequential})})</td>
<td>9 - 10 (Concurrent)</td>
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<tr>
<td><strong>Resource Profile</strong></td>
<td>DemolitionHaulingTruck (size=24 ton) / Hour</td>
<td>0 (CSCP)</td>
<td>0 (CRCP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 (CSCP)</td>
<td>0 (CRCP)</td>
</tr>
<tr>
<td></td>
<td>DemolitionPackingEfficiency</td>
<td>0.5 (Cracking)</td>
<td>0.5 (Cracking)</td>
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<td></td>
<td></td>
<td>0.5 (Cracking)</td>
<td>0.5 (Cracking)</td>
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<tr>
<td></td>
<td>Demolition Team Numbers</td>
<td>1</td>
<td>2</td>
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<td></td>
<td>Concrete Delivery Truck (size=8-5.5 CY) / Hour</td>
<td>10 (CSCP)</td>
<td>15 (CSCP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 (CSCP)</td>
<td>15 (CSCP)</td>
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<tr>
<td></td>
<td>HMA Delivery Truck (size=24 ton) / Hour</td>
<td>10</td>
<td>12</td>
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<tr>
<td></td>
<td>Base Delivery Truck (size=8 CY) / Hour</td>
<td>8</td>
<td>10</td>
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<tr>
<td></td>
<td>Pay Load Speed / Hour</td>
<td>1.5 feet (POG)</td>
<td>7 feet (POG)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5 feet (POG)</td>
<td>7 feet (POG)</td>
</tr>
<tr>
<td></td>
<td>Milling AC Material Type</td>
<td>Milling-Down Efficiency</td>
<td>0.75</td>
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<td></td>
<td>Slurry or Medium (Limestone)</td>
<td>Medium or Hard (granite)</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slurry or Medium (Limestone)</td>
<td>Medium or Hard (granite)</td>
</tr>
<tr>
<td><strong>Work-zone Traffic</strong></td>
<td>RO Route Capacity (veh/hr)</td>
<td>1,800 (Two-lane HWY); 2,200 (Multi-lane HWY)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,200 (Single-lane Open), 1,600 (Multi-lane Open)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vehicle-Capacity Hourly</td>
<td>11.51 (car)</td>
<td>27.03 (truck)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 (car)</td>
<td>27.03 (truck)</td>
</tr>
</tbody>
</table>
I-15 Devore WZ Capacity: Full-closure Dynamic Lane Configuration Using QCMB

QCMB Operation Video
Classification of Traffic Analysis Models

Scale & Level of Detail

Bridging Gap: Transportation Planning and Traffic Operations

Large

Geographic Area

Micro-simulation
- Paramics
- AIMSUN
- VISSIM
- TransModeller
- CORSIM
- SimTraffic

Macro simulation
- DYNASMART
- DynamEQ
- FREQ
- CA4PRS
- Synchro

Meso simulation

Planning Models
- TransCAD
- EMME/2
- TranPlan

High
Level of Detail
Low
I-15 Devore Simulation for TMP: Paramics Microscopic Network Traffic Analysis
Vissim 3-D: Work-zone Lane-closure and Traffic-movement
Challenges: WZ Simulation Tools

• Usability Challenges
  – Limited work zone behaviors: utilize incident functionality
  – Poor menu & interfaces for work zone configuration
  – Need complicated post-analysis process: time & costs
  – Weekend OD is not available: converted from Weekday data (peak-hour commuter traffic).
  – Not enough model for travelers’ learning mechanism
    short-term vs long-term closures (user equilibrium)

• Implementation Challenges
  – Require large amount of data and calibration: time - cost
  – User needs traffic and simulation knowledge (UE & SO)
  – Usually expensive license of commercial package
  – Oftentimes, outsourcing to consultants
CA4PRS => LCCA Integration: I-15 HOT Widening

(a) Plan View: Existing Roadway (NB)

(b) Plan View: After Widening (NB)

(c) Cross-section:
   Long-life (40-y) PCCP

(d) Cross-section:
   Standard-life (20-y) ACP
I-15 Riverside Widening Life-Cycle Cost (30 analysis)

<table>
<thead>
<tr>
<th>Type</th>
<th>Construction</th>
<th>Life</th>
<th>Year</th>
<th>AGENCY COST ($ Millions)</th>
<th>NPV</th>
<th>Discounted</th>
<th>Un-discount</th>
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</thead>
<tbody>
<tr>
<td><strong>PCCP (40-year Long-life)</strong></td>
<td>PCCP Widening</td>
<td>40</td>
<td>2015</td>
<td>$46</td>
<td></td>
<td>$46</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1st PCCP CAPM</td>
<td>5</td>
<td>2055</td>
<td>$1</td>
<td></td>
<td>$1</td>
<td>$3</td>
</tr>
<tr>
<td></td>
<td>2nd PCCP CAPM</td>
<td>5</td>
<td>2060</td>
<td>$2</td>
<td></td>
<td>$2</td>
<td>$9</td>
</tr>
<tr>
<td></td>
<td>3rd PCCP CAPM</td>
<td>10</td>
<td>2065</td>
<td>$2</td>
<td></td>
<td>$2</td>
<td>$11</td>
</tr>
<tr>
<td>Annual Maint. Cost</td>
<td></td>
<td></td>
<td></td>
<td>$1</td>
<td></td>
<td>$1</td>
<td>$2</td>
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<td><strong>PCCP Total</strong></td>
<td></td>
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<td>$51</td>
<td></td>
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<tr>
<td><strong>ACP (20-year Standard-life)</strong></td>
<td>ACP Widening</td>
<td>20</td>
<td>2015</td>
<td>$38</td>
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<td>$38</td>
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<tr>
<td></td>
<td>1st OGFC</td>
<td>10</td>
<td>2025</td>
<td>$3</td>
<td></td>
<td>$4</td>
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<tr>
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<td>1st ACP CAPM</td>
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<td>2035</td>
<td>$7</td>
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<tr>
<td></td>
<td>2nd ACP CAPM</td>
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<td>2045</td>
<td>$5</td>
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<td>$15</td>
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<tr>
<td></td>
<td>1st ACP Rehab.</td>
<td>20</td>
<td>2055</td>
<td>$5</td>
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<td>$24</td>
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<tr>
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<td>2065</td>
<td>$1</td>
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<td>$4</td>
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<tr>
<td>Annual Maint. Cost</td>
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<td></td>
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<td>$3</td>
<td>$7</td>
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<tr>
<td><strong>ACP Total</strong></td>
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<td>$61</td>
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<td>$108</td>
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<td><strong>Difference (PCCP-ACP)</strong></td>
<td></td>
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<td></td>
<td>($10)</td>
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<td>($37)</td>
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</table>

**ACP needs $8M less Initial Cost, but $10M more LCC than PCCP**
CA4PRS Implementation Issues

• Primary Users
  – Industry: Consultants, Contractors, Vendors

• Candidate Projects
  – Major maintenance, Rehab/Reconstruction, Widening projects
  – High-profile, public outstanding, urban corridor projects

• Implementation Stages
  – The earlier, the better; mainly in Design stage
  – LCCA Interactions

• Analysis time needed
  – Pre-construction Analysis (scenario comparison): 1-2 months
  – Construction-staging plans and TMPs: about 2-3 months
  – Data collection take time
  – Incorporate with WZ network simulation: 6-12 months
CA4PRS Coding Platform

MS Windows (~ Win 7)

Visual Basic 6.0

MS ACCESS DB (backend)
SCHEDULE MODULE
TRAFFIC MODULE