“Integration of ITS into Rural Work Zones”

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Project Objectives

- Develop ITS architecture for rural WZs
- Develop guidelines for use of WZ ITS
- Develop and test proof-of-concept WZ ITS
  - Dynamic queue warning
  - Travel time/delay
## RURAL ROAD WORK GROUPS BY LOCATION

- Work within the Traveled Way of Two-Lane Highways
- Work Within the Traveled Way of Multilane Undivided Highways
- Work Within the Traveled Way of Multilane Divided Highways
- Work Within the Traveled Way of Expressways and Freeways
- Work on the Shoulder
- Work in the Vicinity of Highway-Rail Grade Crossings

## POTENTIAL ITS STRATEGIES/APPLICATIONS

- Dynamic Congestion Advisory
- Dynamic Merge (at work zones with lane closures)
- Dynamic Queue Warning Systems
- Excessive Speed Warning
- Haul Road Warning
- Optimized Restriction/Closure
- Travel Time/Delay Information
- Variable Speed Limit (VSL) / Var Speed Advisory
- Work Space Intrusion Warning
- Other

### Table

<table>
<thead>
<tr>
<th>Description of work</th>
<th>TMUTCD TA-No.</th>
<th>Duration</th>
<th>Schedule</th>
<th>WZ Boundary</th>
<th>Potential Impacts</th>
<th>Potential ITS Solutions</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>L: Long,</td>
<td>24-hr,</td>
<td>S: Stationary,</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>I: Intermed.</td>
<td>D: Day,</td>
<td>M: Mobile</td>
<td>D: Delays</td>
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<tr>
<td></td>
<td></td>
<td>S: Short</td>
<td>N: Night</td>
<td></td>
<td>Q: Queues</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RE: Rear-End Collision</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SC: Side-swipe Collision</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FC: Frontal Collision</td>
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</table>
Develop Guidelines for Use of ITS

- Benefit/Cost Analysis
  - Benefits
    - Delay reduction
    - Crash reduction
  - Costs
    - ITS cost from private provider
Smart Work Zones

- SWZ Queue Warning
  - Speed sensors
  - Portable changeable message sign (PCMS)
  - CPU to process sensor data
  - Communication between CPU & PCMS
**Detected Queue Profiles with Different Speed Thresholds**
Using 1-Minute Moving Average Speed (0.5 Mile Spacing)

- Simulated Queue
- Detected Queue Length (25 mph)
- Detected Queue Length (30 mph)
- Detected Queue Length (35 mph)
Daytime vs nighttime work zones

Source: NCHRP 627
Crash costs in WZ vs AADT

Crash Reduction Cost per Mile
Daytime Work Zones

Cost Reduction

AADT

Crash Reduction Cost per Mile
Nighttime Work Zones

Cost Reduction

AADT
Example

- Cost of SWZ with 4 sensors & 2 PCMSs $71,000
- Length of influence zone: 3.0 mi
- Assumed crash reduction due to SWZ 10%
- AADT 100,000 vpd
- Duration 24 mo, daytime work only
Proof-of-concept testing

- Design Objectives
  - Provide dynamic queue warning
  - Provide reliable estimate of travel time/delay
Smart Work Zone Concept

BT Reader

ℓ_s ℓ_s ℓ_s ℓ_0

Speed Sensor

ℓ_BT

ℓ_WZ

ℓ_DMS ℓ_Q

SLOW TRAFFIC X MILES AHEAD / NEXT X MILES Y MINUTES
Simulation Model

Work Zone Capacity = 1650 vph
Simulation Design

- Queue monitoring
  - Speed-based algorithm

- Travel time monitoring
  - Bluetooth-based system
Design Parameters

- Queue monitoring
  - 35-mph speed threshold
  - 0.5-mile spacing
  - 5-minute aggregation interval
- Bluetooth parameters
  - 1-sec reading frequency
  - 100-m effective range (class 1 device)
Travel Time Comparison: v/c < 1

Comparison of Travel Time Information

- Experienced
- Bluetooth

Simulation Time (seconds) vs. Travel Time (minutes)
Travel Time Comparison: v/c > 1

Comparison of Travel Time Information

- Experienced
- Bluetooth

Simulation Time (seconds)
Travel Time (minutes)
The proposed algorithm for total delay is:

\[ d_{\text{total}} = d_Q + d_{WZ} + d_U \]

- \( d_{\text{total}} \) = Total delay (minutes/veh)
- \( d_Q \) = Delay in queue
- \( d_{WZ} \) = Delay in traveling through the work zone
- \( d_U \) = Unaccounted delay
Estimating Travel Time Using Proposed Algorithm

\[ tt_t = tt_f + d_{Q,t} + d_{WZ,t} + d_{U,t} \]

- \( tt_t \) = Estimated travel time at time \( t \)
- \( tt_f \) = Free-flow travel time (minutes)
Algorithm Performance
Bluetooth Travel Time

Comparison of Travel Time Information

Simulation Time (seconds)

Travel Time (minutes)

- Experienced
- Bluetooth
Algorithm Performance
Proposed Algorithm

Comparison of Travel Time Information

- Experienced
- Proposed

Travel Time (minutes)
Simulation Time (seconds)
# Evaluation Results

<table>
<thead>
<tr>
<th>ID</th>
<th>Peak Volume (vph)</th>
<th>v/c</th>
<th>Ramp Interruption</th>
<th>Volume Profile</th>
<th>RMSE (min)</th>
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<td>BT</td>
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<td>4.25</td>
<td>28%</td>
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Summary of Findings

- **ITS architecture**
  - Stand Alone
  - Integrated

- **Justifying SWZ in rural areas**
  - High AADT
  - \( v/c > 1.0 \)
  - Extended duration

- **Bluetooth travel time**
  - Improvement 6% to 54%

- **Dynamic queue warning**
  - Maximum queue length
  - Speed sensor spacing < 1.0 mi
Contact information

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