Mobile Operation Intrusions

- New York State database
  - 8% of all intrusion crashes
  - 63% vehicle striking truck-mounted attenuator on shadow vehicle
  - 25% driver pulling between work vehicles

- California
  - Survey about experiences
  - 20% of all intrusion crashes
  - Same two reasons cited
Large Speed Differential

- Traffic traveling at high speeds
- Work convoy traveling at slower speeds
- Difficult to discern speed differential
- Driver reactions
  - Extreme braking
  - Last minute lane changes
- Result
  - Near misses
  - Rear end collisions
Vehicles Entering Work Convoy

- Urban roads
  - Drivers enter perpendicular to convoy
  - Drivers cross between work vehicles to reach destination

- Rural two-lane roads
  - Drivers may not know whether they should pass
  - Drivers may not expect additional work vehicles

- Freeways
  - Drivers cross between work vehicles to reach destination
Potential Countermeasures

- Additional shadow vehicles with truck-mounted attenuators
- Advance warning vehicle
- Reduce spacing between work vehicles
- Enforcement
Potential Countermeasures

- Enhanced vehicle warning light systems
- Truck-mounted changeable message signs
- Truck-mounted dynamic speed display signs
Improving the Safety of Moving Lane Closures

Prepared for
2009 Work Zone Safety Conference,
Orlando, FL

Presented by
Doug Steele, P.E.
Purpose

Improve the safety of moving lane closures for the workers and traveling public through study of driver behavior, specifically.....
Influence Drivers To...

- Slow down at work zones
- Vacate the closed lane at a safe distance upstream
- Remain in the open lane until safely beyond
Gather Pertinent Information

- MUTCD
- Standards
- Research
Identification of Hazards

- Individual and group driving characteristics and habits
- Roadway characteristics
- Weather and time of day

Lateral Intrusion into Work Area

Intrusion due to Rear-Impacted TMA
Rollahead Distance

Rollahead distance, ft

- 45 mph
- 62 mph

TMA Truck Weight = 30,000 lbs

Moving vehicle weight, kips

Cars and pickups

Single Unit Trucks

Multiple Unit Trucks

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Expanding the Realm of Possibility™
FIELD TESTS
Locations

- I-90 at Meacham Road, Schaumburg (Urban)
- I-88 at Somonauk Road, Dekalb (Rural)
- I-290 at Laramie Avenue, Chicago (Ramps)
- I-90 at Barrington Road, Hoffman Estates (Night)

Videotaping and speed monitoring was performed for 2-3 days at each location.
Site 1 – I-90 at Meacham Road

- Urban expressway
- 4 lanes per direction
- 90,000 ADT
- Daytime testing
- Studied:
  - Cut-in, -out distances
  - Variable buffer lengths
  - Lead truck
  - Effect of police presence
Buffer Area Tests - Setup

Legend

- PCMS
- TMA w/arrowboard
- Safety Barrel

Inner Shoulder

- Lane 1
- Lane 2
- Lane 3
- Lane 4

Outer Shoulder

Work Area

1500-2500’ 100’ 50’ Var.

Short spacings to prevent intrusions in the taper and work zone
Buffer Area Tests - Setup
Buffer Test - No Barrel

Vehicles, percent

Distance downstream from end of work zone, ft

Traffic Direction

- Cars
- SU's
- MU's
Buffer Test – Barrel at 50 ft

Vehicles, percent

Distance downstream from end of work zone, ft

Traffic Direction

No Intrusions

Work Zone

Cars
SU's
MU's
Buffer Test – Barrel at 100 ft

Vehicles, percent

Distance downstream from end of work zone, ft

No Intrusions

Traffic Direction

0 50 100 150 200 250 300 350 400 450

0 10 20 30

Cars
SU’s
MU’s

Work Zone
Buffer Test – Barrel at 150 ft

Vehicles, percent

- Cars
- SU's
- MU's

Distance downstream from end of work zone, ft

No Intrusions

Work Zone

Traffic Direction

0 50 100 150 200 250 300 350 400 450
Buffer Test – Barrel at 200 ft

Vehicles, percent

Cars
SU's
MU's

Traffic Direction

10 Attempted Intrusions

Work Zone

Distance downstream from end of work zone, ft

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Traffic Control Setup - Lead Truck

Legend

- PCMS
- TMA w/arrowboard
- Safety Barrel

Inner Shoulder

Lane 1
Lane 2
Lane 3
Lane 4

Outer Shoulder

- Lead Truck
- Work Area

1500-2500’
100’
50’
Var.

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Expanding the Realm of Possibility™
Traffic Control Setup - Lead Truck

Legend

- PCMS
- TMA w/arrowboard
- Safety Barrel

Inner Shoulder

Lane 1
Lane 2
Lane 3
Lane 4

Outer Shoulder

Work Area

1500-2500’ 100’ 50’ Var.

Lead Truck

At 100 ft attempted intrusions = 0
At 200 ft attempted intrusions = 0
At 300 ft attempted intrusions = 4
Advance Warning Area - Setup

Legend

- PCMS
- TMA w/arrowboard
- Safety Barrel

Inner Shoulder

- Lane 1
- Lane 2
- Lane 3
- Lane 4

Outer Shoulder

1500-2500’

100’

50’

Performed with and without police

Expanding the Realm of Possibility™
Advance Warning – No Police
Advance Warning – With Police
Cut-Out Distances – No Police

Vehicles / hr

Distance upstream from TMA on shoulder, ft

Traffic Direction

Cars
SU's
MU's

TMA on Shoulder

Expanding the Realm of Possibility™
Cut-Out Distances – Police

**Vehicles / hr**

- **Cars**
- **SU's**
- **MU's**

Traffic Direction

Distance upstream from TMA on shoulder, ft

TMA on Shoulder

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Effect of Police on Speed

Speed, mph

No police - free flowing traffic

Police present - traffic congested

Speed approaching the work zone

Speed at the work zone

9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM

Time
Site 2 – I-88 at Somonauk Road

- Rural interstate
- 2 lanes per direction
- 13,500 ADT
- Daytime testing
- Studied:
  - Cut-in, -out distances
  - Lead truck
  - Alternative messages
  - Effect of police presence
Traffic Control Setup - Rural

Legend

- Truck-mounted PCMS
- TMA w/arrowboard
- Channel truck w/arrowboard
- Supervisors truck

Lane 1
- 1500'

Lane 2
- 500'
- 500'
- 500'
- 500'
- 50'

Inner Shoulder

Work Area

Outer Shoulder

4 trucks with 500’ spacing between each
Overview - Buffer Tests
Addition of Lead Truck

Legend

- Truck-mounted PCMS
- TMA w/arrowboard
- Channel truck w/arrowboard
- Supervisors truck

Inner Shoulder

Lane 1

Lane 2

Work Area

Outer Shoulder

Foreman’s pickup 300’ downstream of lead TMA and on shoulder
Lead Truck on Shoulder
Cut-In Distances - Rural

Vehicles per hour

Cut-in distance, ft

Traffic Direction

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Cut-In Distances – Lead Truck

Vehicles per hour

Cut-in distance, ft

- Cars
- SU's
- MU's

Traffic Direction

Supervisor's Truck

Lead TMA

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Free Flowing Traffic Speeds

Speed, mph

Average speed

Time

9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM

- Speed approaching the work zone
- Speed at the work zone

Speed deviation
Advance Warning Area
Advance Warning Setup - Rural

Legend
- Truck-mounted PCMS
- TMA w/arrowboard
- Channel truck w/arrowboard
- Supervisors truck

Somonauk Road Br.

Lane 1
Lane 2

Inner Shoulder

Outer Shoulder

2200’
Rural Cut-Out Distances

Vehicles, percent

- No police
- Police present

5.6 percent vehicles came within 500 ft of the work zone without police present, versus just 0.7 percent with police.

Distance upstream vehicles vacate the lane, ft

- > 3000'
- 3000'- 2200'
- 2200'- 500'
- 500'- 0'
- < 0'

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Alternative Messages and Police Effect on Speed

- Alternative messages
  - Right Lane Closed (base case)
  - Reduce Speed
  - Reduce Speed 45 mph
- Police presence
Effect of Various Messages

Speed, mph

- Right Lane Closed
- Reduce Speed
- Right Lane Closed
- Reduce Speed 45 MPH
- Police Present
- Right Lane Closed
- Right Lane Closed
- Average approaching speed
- Average speed at the work zone

Time of day

9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM
Site 3 – I-290 at Laramie Ave.

- Urban expressway
- 4 lanes per direction
- 180,000 ADT
- Daytime testing
- Studied:
  - Cut-in, -out distances
  - Behavior near ramps
Typical Setup – 2-Truck Taper

2-truck taper, 500-ft spacing between trucks. TMA2 provides a buffer between it and TMA1.
Cut-In Distance – Setup

Lead TMA
Cut-In – Heavy Congestion

Vehicles / hr

Traffic Direction

Distance downstream from work zone, ft
2-Truck Taper – Approach View
Cut-Out – Heavy Congestion

Vehicles / hr

Traffic Direction

Distance upstream from TMA blocking the lane, ft

Cars
SU's
MU's
Heavy Congestion, Low Speeds

Speed, mph

- Speed approaching the work zone
- Speed at the work zone

Trucks took a loop to relieve congestion

Average speed

Speed deviation

Time

9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM
Conflict Area - Behind TMA

TMA is obscured

Appears suddenly

TMA on Shoulder

2-truck taper produces an abrupt lane closure and a high conflict area behind the TMA blocking the lane
Weaving Traffic at Ramps

Legend:
- TMA w/arrowboard
- Advance warning truck w/lane closed sign

Diagram:
- Laramie Road Br.
- Off Ramp to Laramie
- Outer Shoulder
- Gore Area
- Auxiliary Lane
- Inner Shoulder
- Work Area

Legend:
- Lane 1
- Lane 2
- Lane 3
- Lane 4

Dimensions:
- 500' length markings
Weaving Traffic at Ramps

1 vehicle crossed from lane 3 to the off ramp between the TMAs
Weaving Traffic at Ramps

1 vehicle crossed from lane 3 to the off ramp between the TMAs
7 weaves in between TMAs 1 and 2
Weaving Traffic at Ramps

1 vehicle crossed from lane 3 to the off ramp between the TMAs
7 weaves in between TMAs 1 and 2
13 vehicles crossed from the off ramp to lane 3 between the TMAs
Site 4 – I-90 at Barrington Road

- Urban expressway
- 3 lanes per direction
- 80,000 ADT
- Night testing
- Studied:
  - Lane reflector replacement
  - Cut-in, -out distances
  - Additional “buffer” truck
Two-Lane Closure at Night

Legend

PCMS
TMA w/arrowboard
Work truck w/arrowboard
Supervisors truck

Inner Shoulder
Lane 1
Lane 2
Lane 3

Outer Shoulder

Work Area

Close two lanes to work on lane stripe. Message board is on opposite shoulder.
Foreman’s Truck 500’ Upstream

Foreman’s truck placed 500 ft upstream on shoulder to compensate for short taper length.
Supervisor’s Truck on Shoulder

The addition of a flashing vehicle 500’ upstream of the TMAs provides increased visibility and warning to motorists.
Flashin
Vehicle Upstream

Vehicles per hour

Without pickup

With pickup

Scenario

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Modified Truck Configuration

Supervisor’s truck

Buffer truck

Work truck (serves as lead truck)

The buffer truck provides additional distance between the workers and the potential point of impact.
FINDINGS
Urban vs. Rural Driving Habits

- Significant difference in driver characteristics and behavior
  - Traffic volumes and speeds
  - Aggressiveness, cut-in, -out, distances, responses to signs
- Standards typically do not differentiate. Present minimum requirements
Cut-in Distances and Buffer Spaces

- **Urban**
  - Vehicles cut-in quickly, typically 50 to 100 ft. May be as short as 20 ft
  - Field crews have adapted with tight truck spacing.
  - Need to compensate with additional advance warning
  - At 200 ft buffer spacing, incursions begin
  - With lead truck, incursions begin with a 300 ft buffer

- **Rural**
  - Cut-in distances are longer, typically 100 to 250 ft
  - Lead truck on shoulder, extends cut-in to 200 to 400 ft
Cut-out Distances

- **Urban**
  - Free flow – typically 500 to 1200 ft upstream, small percentage transition in the taper
  - Congestion – approach closer, but at slower speed

- **Rural**
  - 52.5 percent > 3000 ft upstream
  - 94.4 percent > 500 ft upstream
  - 5.6 percent < 500 ft upstream (i.e., “close”), including 0.8 percent in the taper
  - With police present, only 0.7 percent close, none in the taper
Trucks

- Lead truck
  - Was effective at extending the length of the safe work zone (i.e., buffer area + work space) in both urban and rural areas

- Buffer truck
  - Addition of a buffer truck in the convoy increases the distance between workers on foot and potential impacts
  - Requires an additional truck

- Bomber
  - Effective at blocking the shoulder in highly congested, urban areas
Messages and Police

- Messages
  - Choice of PCMS message had a positive effect on speed reduction in rural areas.
  - Urban areas – alternative messages were not tested (no likely benefit)
  - Both cases, the illuminated sign itself seemed to have as much of an impact as the message
  - Use of a flashing vehicle with no sign on the shoulder had a positive “lane change” effect at night

- Police
  - Had a positive effect in almost every aspect, especially speed and cut-out distance
Other Pertinent Issues

- Balance between safety and mobility
- Public perception of maintenance operations
  - View as an inconvenience, not a work zone
  - Speed reductions are suggested, not mandatory
- Allowed duration for intermittent activities
  - Assess increased risk for longer durations, versus
  - Hazards and practicality of stationary lane closures
- What helps? “More trucks, more police” the most frequent answer
Recommendations

- Separate standards for urban and rural roadways
- Develop standards that incorporate:
  - Lead trucks
  - Buffer trucks
  - Guidelines for truck spacing and buffer spacing
  - Adequate transition area and truck tapers
  - Effective messages
- Update standards to:
  - Incorporate proposed modifications
  - Clarify (e.g., when to use one vs. another)
  - Simplify (to increase likelihood of conformance)
  - Promote agreement between standards and field practices
Continuation of Research

- Phase II is underway
- Scope will include:
  - Large group discussions
  - Expert panel group
  - Recommendations for improvements to current standards
Thank You!

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