Work Zone Crash Modification Factors

2018 National Work Zone Management Conference
Herndon, Virginia
September 12, 2018

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How to Decide?

• Should I widen the work zone shoulder?

• Should I install an end of queue warning system?

• Should I offer the contractor an incentive to finish early?

Three letters can help…

CMF!

(Crash Modification Factor)
Presentation Overview

- Introduction
- Background
- DOT Practices for WZ Safety
- Work Zone CMFs
- Application of Existing CMFs
- Development of New CMFs
- Conclusions
Motivation

• Limited work zone CMF availability (HSM, CMF Clearinghouse)
• Work zone data challenges
• Ongoing work zone CMF research
• Need for training
I. Introduction

What is a CMF?

• Provides the expected change in crash frequency due to:
  • the implementation of a countermeasure or
  • a change in a particular site
• CMF Clearinghouse
  • Online repository of CMFs
  • Funded by FHWA
• Example: widen inside WZ shoulder by 1’
  • CMF = 0.97 (CMF Clearinghouse)
  • 3% reduction in crashes
I. Introduction

Goals and Objectives

Goal

• Improve work zone safety

Objectives

• Increase awareness and use of work zone CMFs
• Encourage development of work zone CMFs
• Compile existing knowledge and incorporate new work zone CMFs
• Provide training
I. Introduction

Poll Overview

Who has the best pizza in Columbia?

- Gumbys Pizza: 14.3%
- Pizza Hut: 0%
- Pizza Tree: 0%
- Shakespeare's: 42.9%
- Wiseguys: 14.3%
- Other: 28.6%
I. Introduction

Poll Access

http://etc.ch/Sak6
Poll Question 1

How would you categorize your existing knowledge of work zone CMFs?

a. High  
b. Moderate  
c. Low  
d. None

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II. Background

Development of WZ CMF Guidance

- WZ CMF Guide
  - Completed: Dec. 2017
  - Guidance for practitioners and researchers

- Upcoming Deliverables
  - Inventory of existing WZ CMFs
  - Quick reference guide
  - Training
  - Completion Date: February 2022
SPF and CMF Overview

\[ N_{\text{predicted}} = N_{SPF} \times CMF_1 \times CMF_2 \ldots \times C \]

(AASHTO 2014)

Where:

- \( N_{\text{predicted}} \): predicted crash frequency
- \( N_{SPF} \): predicted crashed frequency (base conditions)
- \( CMF_i \): Crash Modification Factor (adjustment from base condition)
- \( C \): Calibration Factor
III. DOT Practices for WZ Safety

Survey for Safety Tool Project: Overview

- DOT Survey
  - 10 Questions
  - 26 Responses
- Contractor Survey
  - 17 Questions
  - 8 Responses
Survey for Safety Tool Project: Results

How do you account for safety in work zone planning/design? (check all that apply)
Survey for Safety Tool Project: Results

• To what degree do you believe that the following factors impact work zone safety on freeways? (from Not Important to Highly Important)

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Rating Average (DOT)</th>
<th>Rating Average (Contractors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td>3.58</td>
<td>3.38</td>
</tr>
<tr>
<td>lane closure</td>
<td>3.23</td>
<td>3.00</td>
</tr>
<tr>
<td>Work zone warning signs</td>
<td>3.19</td>
<td>3.13</td>
</tr>
<tr>
<td>Moving WZ</td>
<td>3.15</td>
<td>3.25</td>
</tr>
<tr>
<td>Duration</td>
<td>3.12</td>
<td>2.50</td>
</tr>
<tr>
<td>Number of on-off ramps</td>
<td>3.08</td>
<td>2.75</td>
</tr>
<tr>
<td>Urban versus rural</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>Speed decrease</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>Lane shift/crossover</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Length</td>
<td>2.85</td>
<td>2.25</td>
</tr>
<tr>
<td>Work on shoulder</td>
<td>2.58</td>
<td>2.63</td>
</tr>
<tr>
<td>Terrain (flat, rolling)</td>
<td>2.54</td>
<td>2.75</td>
</tr>
<tr>
<td>Incentive/disincentives, cost+time</td>
<td>2.19</td>
<td>2.50</td>
</tr>
<tr>
<td>Cost per mile per duration</td>
<td>1.96</td>
<td>2.00</td>
</tr>
</tbody>
</table>
Q2 Do you believe, generally, that the presence of work zones increases the crash frequency?

Answered: 26   Skipped: 0
III. DOT Practices for WZ Safety

Survey for Safety Tool Project: Results (DOT)

To what degree do you believe that the following additional factors impact the safety of work zones on facilities with at-grade intersections? (from Not Important to Highly Important)
III. DOT Practices for WZ Safety

DOT Interviews: Participants

- 12 State DOTs
- Washington County, MN
- District of Columbia DOT
III. DOT Practices for WZ Safety

DOT Interviews: Practices

• Frequent use of engineering judgement in work zone safety
• Some DOTs (e.g. Oregon, Ohio) perform formal evaluation
• Lack of use of work zone CMFs (lack of awareness, lack of guidance, shortage of staff/resources, limited CMFs, etc.)
III. DOT Practices for WZ Safety

DOT Interviews: Lack of Use of Work Zone CMFs

• Lack of availability of WZ CMFs
• Concerns about CMF reliability and transferability
• Lack of guidance regarding use of WZ CMFs
• Lack of time or staffing
• Unsure of how to apply the work zone CMFs
• Find using CMFs to be overwhelming
• Believe that the use of CMFs is hard to sell to public
Poll Question 2

Which of the following presents the greatest challenge in work zone safety?

a. Data issues  
b. Distracted driving  
c. Design changes  
d. Education/Training  
e. Enforcement

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III. DOT Practices for WZ Safety

DOT Interviews: Challenges

- Keeping motorists informed
- Distracted driving
- Design changes
- Ensuring that work zones meet specifications
- Variability in the work zone on a day to day basis
- Need for training and education for contractors and the agency
- Providing for the safe ingress and egress of work vehicles
- Nighttime work zones (visibility)
- Work zone intrusions
- Speed management
- Getting data for work zone analysis
- Older drivers
IV. Work Zone CMFs

HSM Work Zone CMFs

Work zone duration

\[
CMF_{d,all} = 1.0 + \frac{\left(\% \text{ increase in duration} \times 1.11\right)}{100}
\]

Work zone length

\[
CMF_{l,all} = 1.0 + \frac{\left(\% \text{ increase in length} \times 0.67\right)}{100}
\]
IV. Work Zone CMFs

CMF Clearinghouse

- **Active work (temporary lane closure)**
- **Two-way two-lane work zone operations**
- **Active work (no lane closure)**
- **Increase inside or outside shoulder width**
- **Left-hand merge and downstream lane shift**
- **No active work with no lane closure**

Source: [http://www.cmfclearinghouse.org/](http://www.cmfclearinghouse.org/)
### Existing Work Zone CMFs

<table>
<thead>
<tr>
<th>Description</th>
<th>Severity</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Work with no Lane Closure (Daytime)*</td>
<td>Fatal/Injury</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td>PDO</td>
<td>1.40</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>1.31</td>
</tr>
<tr>
<td>Active Work with no Lane Closure (Nighttime)**</td>
<td>Fatal/Injury</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>PDO</td>
<td>1.67</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>1.58</td>
</tr>
<tr>
<td>Active Work with Temporary Lane Closure (Daytime)*</td>
<td>Fatal/Injury</td>
<td>1.46</td>
</tr>
<tr>
<td></td>
<td>PDO</td>
<td>1.81</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>1.66</td>
</tr>
<tr>
<td>Active Work with Temporary Lane Closure (Nighttime)**</td>
<td>Fatal/Injury</td>
<td>1.42</td>
</tr>
<tr>
<td></td>
<td>PDO</td>
<td>1.75</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>1.61</td>
</tr>
<tr>
<td>No Active Work with No Lane Closure (Daytime)*</td>
<td>Fatal/Injury</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>PDO</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>1.13</td>
</tr>
<tr>
<td>No Active Work with No Lane Closure (Nighttime)**</td>
<td>Fatal/Injury</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>PDO</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>1.24</td>
</tr>
<tr>
<td>Implement left-hand merge and downstream lane shift</td>
<td>All</td>
<td>2.24</td>
</tr>
</tbody>
</table>

*Daytime : 6 am to 7 pm  **Nighttime : 7 pm to 6 am
## Existing Work Zone CMFs

<table>
<thead>
<tr>
<th>Description</th>
<th>Severity</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase the outside shoulder width inside the WZ by one foot</td>
<td>All</td>
<td>0.95</td>
</tr>
<tr>
<td>Increase the inside shoulder width inside the WZ by one foot</td>
<td>All</td>
<td>0.97</td>
</tr>
<tr>
<td>Two-way traffic operation-crossover closure</td>
<td>All</td>
<td>1.00</td>
</tr>
<tr>
<td>Implement mobile automated speed enforcement system*</td>
<td>Fatal/Injury</td>
<td>0.83</td>
</tr>
<tr>
<td>End of Queue Warning System (Nighttime)*</td>
<td>All</td>
<td>0.56</td>
</tr>
<tr>
<td>Portable Rumble Strips - No Queue (Nighttime)*</td>
<td>All</td>
<td>0.89</td>
</tr>
<tr>
<td>Portable Rumble Strips - Queued (Nighttime)*</td>
<td>All</td>
<td>0.40</td>
</tr>
<tr>
<td>EOQ Warning System and Portable Rumble Strips - No Queue (Nighttime)*</td>
<td>All</td>
<td>0.72</td>
</tr>
<tr>
<td>EOQ Warning System and Portable Rumble Strips - Queued (Nighttime)*</td>
<td>All</td>
<td>0.47</td>
</tr>
</tbody>
</table>

*Nighttime: 7 pm to 7 am  
#CMF based on non-work zone data
Other WZ CMFs

- La Torre et al. (2017)
  - Lane closure configuration for four-lane and six-lane freeways
  - Based on data from Italy
- Use of non-work zone CMFs may be appropriate in certain situations
Examples of Other WZ Safety Studies (No CMFs)

- Venugopal and Tarko (2000)
  - Duration, length, AADT, cost, type of work
- Ozturk et al (2013)
  - Temporal adjusted daytime and nighttime volumes, length duration
- Chen and Tarko (2014)
  - Safety effects of lane shift, lane split, and detour
- Wei et al. (2017)
  - Three lighting conditions, number of closed lanes, impaired driving
- Brown et. al (2016) and Brown et al. (2018)
  - Work zone safety assessment tool
IV. Work Zone CMFs

WZ Countermeasures Evaluated by MU

- Mobile work zone alarms
- Automated Flagger Assistance Device
- Use of Green Lights on TMAs
- Evaluations based on surrogate measures
  - Speeds
  - Merge distances
  - Driver behavior
IV. Work Zone CMFs

Poll Question 3

In which of the following general categories do you think there is the greatest need for new work zone CMFs to be developed?

a. Enforcement
b. Positive protection
c. Work zone configurations
d. Work zone ITS

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IV. Work Zone CMFs

Need for Additional WZ CMFs: DOT Interviews

- Weaving sections
- Temporary raised rumble strips
- Divided highway crossover versus lane closures
- Lane width and shoulder width
- 3, 2, or 1 cone procedures for flagger operations
- Steel barrier versus concrete barrier
- Shy distance to barrier
- Use of tubular marker versus drums for lane closure
- Road closure with detour versus staged construction (1 lane closed)
- Early lane merge, late lane merge, zipper merge
- Temporary portable signal versus 24-hour flagging
- Presence of law enforcement
- Automated speed enforcement
- Work zone intrusion alarms
- Traffic sensor message board to say when construction vehicle entering or leaving site
- Wrong way driving prevention
V. Application of Existing CMFs

Using Existing CMFs

1. Identify countermeasures for analysis
2. Determine CMF availability
3. Determine countermeasure evaluation criteria
4. Data collection
5. Perform analysis
6. Select countermeasures for implementation
Example: Outside Shoulder Width

- **Step 1**: Identify countermeasures for analysis
  - Increase outside shoulder width by 1 ft

- **Step 2**: Determine CMF availability
  - CMF = 0.948 (CMF Clearinghouse)

- **Step 3**: Determine countermeasure evaluation criteria
  - Implement if B/C > 1.5

- **Step 4**: Data collection
  - Improvement cost = $3,000 / mile
  - Project length = 2 miles
  - Expected number of crashes = 8
  - Crash cost = $86,000
V. Application of Existing CMFs

Example: Outside Shoulder Width

• Step 5: Perform analysis
  • Estimated improvement costs = 2 miles * $3,000/mile = $6,000
  • Estimated crash reduction = (1 – 0.948) * 8 = 0.416 crashes
  • Estimated crash cost savings = 0.4 crashes * $86,000/crash = $35,776
  • B/C = $35,776 / $6,000 = 5.96

• Step 6: Select countermeasures for implementation
  • B/C > 1.25 Implement!
Example: End of Queue Warning System (Nighttime)

• Step 1: Identify countermeasures for analysis
  o Implementation of the End-of-Queue warning system (nighttime)

• Step 2: Determine CMF availability
  o CMF = 0.56 (CMF Clearinghouse)

• Step 3: Determine countermeasure evaluation criteria
  o Implement if B/C > 2.0

• Step 4: Data collection
  o Improvement cost = $250,000 / each
  o Expected number of crashes = 11
  o Crash cost = $86,000
Example: End of Queue Warning System (Nighttime)

• Step 5: Perform analysis
  • Estimated improvement costs for one unit = $250,000
  • Estimated crash reduction = \((1 - 0.56) \times 11 = 4.4\) crashes
  • Estimated crash cost savings = \(4.4\) crashes \(\times\) $86,000/crash = $378,400
  • \(B/C = \frac{378,400}{86,000} = 1.51\)

• Step 6: Select countermeasures for implementation
  • \(B/C < 2.0\) \(\rightarrow\) Do not implement!
VI. Development of New CMFs

Developing New CMFs

1. Select countermeasure for CMF development
2. Select method for CMF development
3. Assess data needs and availability
4. Select sites
5. Data collection
6. Calculate CMFs
7. Evaluate results
VI. Development of New CMFs

Example: WZ Length and Duration

• Step 1: Select countermeasure for CMF development
  • Work zone length
  • Work zone duration

• Step 2: Select method for CMF development
  • Cross-sectional study (using negative binomial regression)

• Step 3: Assess data needs and availability
  • Missouri Department of Transportation (MoDOT) databases
    • Work zone database
    • Crash database
    • Road segment database

Source: Rahmani et al., 2016
VI. Development of New CMFs

Example: WZ Length and Duration

• Step 4: Select sites
  - 1,571 freeway work zones in Missouri (2009-2014)
  - Minimum work zone length = 0.1 mile
  - Minimum work zone duration = 10 days

• Step 5: Data collection
  - Spatial and temporal matching of data
  - Assignment of crashes to work zone locations

• Step 6: Calculate CMFs
  \[ CMF_{Length} = 1.0 + \frac{\text{% increase in Length} \times 0.62}{100} \]
  \[ CMF_{Duration} = 1.0 + \frac{\text{% increase in Duration} \times 1.01}{100} \]
VII. Conclusions

Conclusions

• Use of WZ CMFs can help to evaluate countermeasures
• Need for practitioner guidance on WZ CMFs
• Need for additional WZ CMFs
• WZ CMF Guide freely available at https://goo.gl/JoDtme
• Training materials under development
Acknowledgements

• WZ Safety Grant funded by FHWA
• Safety Tool project funded by Smart Work Zone Deployment Initiative
• Jawad Paracha (FHWA Program Manager)
• Personnel who participated in surveys and interviews
• MU Students
  • Farzaneh Azadi
  • Roozbeh Rahmani
VII. Conclusions

References


Questions?

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Link to WZ CMF Guide

https://goo.gl/JoDtme

Thank you!