Recent Research in Pedestrian Crash Prediction and Countermeasures

We are all pedestrians!
Where We Are

- Safety of pedestrians is of high concern
- Pedestrians are very vulnerable in crashes with vehicles
- Veh-Ped crashes are typically of higher severity
- With aging population and encouragement of active transportation, potential for veh-ped crashes may increase
Where We Are

• Safety management is rightfully moving towards quantitative methods backed by empirical evidence.
• Significant research has been undertaken into predicting vehicle crashes and effectiveness of countermeasures.
• AASHTO’s Highway Safety Manual is a result of much of this research.
• Analysis methods and knowledge mostly related to vehicle-vehicle or single-vehicle crashes.
Where We Are

- Knowledge for veh-ped crashes is limited
- Relative rarity of veh-ped crashes is a factor
- Popularity of Vision Zero type plans increasing
- With higher severity, veh-ped crashes need to be a focus area
- More research into developing quantitative methods for veh-ped crashes is needed
Recent Efforts

- Study 1 – Development of Safety Performance Functions (SPFs) for vehicle-pedestrian crashes in Region of Waterloo
- Study 2 – Development of Crash Modification Factors (CMFs) for vehicle-pedestrian crashes
Veh-Ped Crash SPFs for Region of Waterloo

- SPF is an equation that predicts the average crash frequency at a site

Crashes per year = \( \exp\left(-5.5368\right) \cdot \text{AADT}^{0.6622} \)
Veh-Ped Crash SPFs for Region of Waterloo

• SPFs are applied in various safety management tasks
  – Methods for ranking sites for improvement
  – Selection of countermeasures
  – Economic appraisal
  – Evaluation of countermeasures
Veh-Ped Crash SPFs for Region of Waterloo

- Study led by CIMA+
- Objective was to develop SPFs for crashes for segments and intersections in Waterloo
- Included SPFs for veh-ped and veh-bike crashes
- Sought to relate the number of crashes expected to a site’s traffic volume and other road characteristics
Veh-Ped Crash SPFs for Region of Waterloo

- **Midblock**
  - City two-lane Undivided
  - City three-lane Undivided
  - City four-lane Undivided
  - City 5/6 Lane Undivided
  - City two-lane (1 Way)
  - City 3/4-lane (1 Way)
  - City two-lane Divided
  - City 4-lane Divided
  - City 5/6 Lane Divided
  - Township All Lanes Undivided

- **Intersection**
  - Signalized
    - City 3-Legged
    - City 4-Legged
    - Township 3&4-Legged
  - Unsignalized
    - City 3-Legged
    - City 4-Legged
    - Township 3-Legged
    - Township 4-Legged
Waterloo Segment SPFs

\[ E(Y) = \exp^{-11.0672 \times F^{0.7056} \times L^{0.2901} \times \exp^{-0.6933 \times \text{LANES} + 0.4845 \times \text{MEDIAN} + 0.7335 \times \text{LOC}}} \]

Where,

- **E(Y)**: Predicted number of vehicle-pedestrian crashes per year;
- **F**: average annual daily traffic;
- **L**: segment length in kilometres;
- **LANES**: 1 if a 2 or 3 lane roadway; 0 if greater than 3 lanes;
- **MEDIAN**: 1 if no median present; 0 if median present; and,
- **LOC**: 1 if a city location; 0 if a township location.
Veh-Ped Crash SPFs for Region of Waterloo

Waterloo Signalized Intersection SPFs

\[ E(Y) = \exp^{-7.8958 \times F_{tot}^{0.4473} \times \exp^{-0.5970 \times \text{LEGS} + 1.8684 \times \text{LOC}}} \]

Where,

- \( E(Y) \): Predicted number of vehicle-pedestrian crashes per year;
- \( F_{tot} \): Total entering volume of intersection per day;
- \( \text{LEGS} \): 1 if a 3 leg intersection; 0 if 4 leg intersection, and
- \( \text{LOC} \): 1 if a city location; 0 if a township location.
Veh-Ped Crash SPFs for Region of Waterloo

Waterloo Unsignalized Intersection SPFs

\[ E(Y) = \exp^{-12.7878} \times F_{maj}^{0.5429} \times F_{min}^{0.4111} \times \exp^{-1.3915} \times \text{LEGS} + 1.3939 \times \text{LOC} \]

Where,

\( E(Y) \): Predicted number of vehicle-pedestrian crashes per year;

\( F_{maj} \): Total entering volume of major road per day;

\( F_{min} \): Total entering volume of minor road per day;

\( \text{LEGS} \): 1 if a 3 leg intersection; 0 if 4 leg intersection, and

\( \text{LOC} \): 1 if a city location; 0 if a township location.
Development of Veh-Ped CMFs

NCHRP 17-56 [Active]

Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments

<table>
<thead>
<tr>
<th>Project Data</th>
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</thead>
<tbody>
<tr>
<td>Funds:</td>
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<tr>
<td>Staff Responsibility:</td>
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<tr>
<td>Research Agency:</td>
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<tr>
<td>Principal Investigator:</td>
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<tr>
<td>Effective Date:</td>
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<tr>
<td>Completion Date:</td>
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BACKGROUND

There is considerable uncertainty and confusion surrounding the use of pedestrian crossing treatments at uncontrolled locations. Research shows that marking crosswalks without making improvements is associated with higher pedestrian crash rates under certain roadway configurations and operating characteristics (Zegeer, C.H., Stewart, J.R., Huang, H.H., and Lagerway Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations, Federal Highway Administration, 2001). However, failing to provide crossing opportunities or over-improving an already undesirable solution increases pedestrian crashes, Zegeer et al. recommend enhanced crossing treatments, noting that "pedestrian crossing problem should be routinely identified, and appropriate solutions should be selected to improve pedestrian safety and access." While several studies have examined pedestrian safety at uncontrolled locations, robust crash modification factors (CMFs) are generally lacking. Research is needed to enable state and local transportation agencies to quantify the safety benefits of pedestrian treatments and to incorporate these treatments into their safety programs.

OBJECTIVES

The objectives of this research are to (1) quantify the relationships between pedestrian safety and crossing treatments at uncontrolled locations (excluding roundabouts) and (2) develop CMFs to evaluate the effectiveness of pedestrian crossing treatments. The CMFs include (a) unsignalized pedestrian crosswalk signs and pavement markings, including advance yield markings; (b) high-intensity activated crosswalk (HAWK) signals; (c) rectangular rapid flashing beacons; (d) pedestrian refuge areas; (e) curb extensions; (f) in-pavement warning lights; and (g) high-visibility crosswalk marking patterns. The quality of data used should facilitate inclusion into the AASHTO Highway Safety Manual.
Development of Veh-Ped CMFs

• A CMF is a multiplier representing expected change in crashes due to treatment
• CMFs can be used to estimate safety benefit when implemented at a site

4-legged signalized intersection on rural multilane road; major road AADT of 30,000 and minor road AADT of 5,000; no turn lanes

Consider adding a left-turn lane on one approach of major road.

CMF = 0.82

Expected crashes without left-turn lane = 6.3
Expected crashes with left-turn lane = (6.3)(0.82) = 5.2
Development of Veh-Ped CMFs

• CMFs developed for pedestrian crossing treatments at unsignalized crossings
• Data represents multiple cities in U.S.
• Treatments include:
  – Rectangular Rapid Flashing Beacons (RRFBs)
  – Pedestrian Hybrid Beacons (PHBs)
  – Pedestrian Refuge Islands
  – Advance Yield or Stop Markings or Signs
Development of Veh-Ped CMFs
Development of Veh-Ped CMFs
Development of Veh-Ped CMFs

PHB (HAWK) (High intensity Activated crossWalk)
Development of Veh-Ped CMFs

Refuge Islands
Development of Veh-Ped CMFs

Advance Stop

Advance Yield
Development of Veh-Ped CMFs

• 975 Treatment and Comparison sites collected from 14 cities
• Most sites on multi-lane streets
• Treatment, geometric, traffic and pedestrian exposure characteristics collected
• Results based on cross-sectional regression models
• Some limited EB before-after results confirmed logic of results
Development of Veh-Ped CMFs

\[
\text{PEDCRASH/yr} = \exp^{-7.1959 + \text{City} - 0.3930 \times \text{PHB Presence} - 0.5695 \times \text{AreaType} \times \text{AADT}^{0.3802} \times \text{PEDAADT}^{0.3141}}
\]

Where,
- AADT = total AADT on roadway being crossed
- PEDAADT = total pedestrian AADT for midblock or intersection
- AreaType = 1 if Suburban; 0 if Urban
- City = represents an intercept term specific for each city
- PHB Presence = 1 if present; 0 if not present

\[
\text{CMF} = \exp^{-0.3930} = 0.675
\]
## Development of Veh-Ped CMFs

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crash Type</th>
<th>Recommended CMF</th>
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<tr>
<td></td>
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<td>Estimate</td>
<td>Standard Error</td>
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<td><strong>Refuge Islands</strong></td>
<td>Pedestrian</td>
<td>0.685</td>
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<td></td>
<td>Total</td>
<td>0.742</td>
<td>0.071</td>
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<tr>
<td></td>
<td>All Injury</td>
<td>0.714</td>
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<td></td>
<td>RE+SS</td>
<td>0.741</td>
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<td>RE+SS Injury</td>
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<td><strong>Advance Yield/Stop</strong></td>
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<td>Total</td>
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<td>RE+SS</td>
<td>0.800</td>
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<td><strong>PHB</strong></td>
<td>Pedestrian</td>
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<td><strong>PHB+Advance Yield/Stop</strong></td>
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<td>Total</td>
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<td>RE+SS</td>
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<td><strong>RRFB</strong></td>
<td>Pedestrian</td>
<td>0.526</td>
<td>0.377</td>
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</table>
Conclusions

- Reducing veh-ped crashes is a high priority
- Considering the higher severity and Vision-Zero type goals is especially true
- Quantitative measures needed for veh-ped safety management tasks, including SPFVs and CMFs
- Rarity of crash type presents challenges
- Recent research is beginning to fill the knowledge gaps