EVALUATING THE SAFETY EFFECTS OF INTERSECTION SAFETY DEVICES AND MOBILE PHOTO ENFORCEMENT AT THE CITY OF EDMONTON
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City of Edmonton Office of Traffic Safety

Introduction

Types of Speed Enforcement
- Conventional speed enforcement
- Automated speed enforcement
  - Fixed photo enforcement
  - Mobile photo enforcement

Fixed Enforcement at Intersections – ISD Cameras
- Estimate the collision reduction effect at both an intersection level and approach specific level
- Investigate the spillover effects to unenforced approaches
- Identify intersection characteristics that impact ISD success

Mobile Photo Enforcement on Arterials
- Estimate the collision reduction effect on enforced arterial segments
- Compare different enforcement strategies (continuous vs. discontinuous)
- Investigate the spillover effects on unenforced adjacent approaches
Intersection Safety Devices

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ISD Evaluation - Contents

- Introduction
  - What are Intersection Safety Devices?
- Background
  - Collisions at Intersections
  - Summary of Previous Works
- Methodology
  - Before-and-After Evaluation
  - Data Description
- Results
  - Intersection Level Results
  - Approach Level Results
- Conclusion
  - Summary of Findings
  - Further Benefits of ISD

ISD Research Breakdown
Introduction

Intersection Safety Cameras

• Red light Cameras (RLC)
  Targets drivers who enter the intersection after the red-light

• Intersection Safety Devices (ISD)
  Targets drivers who are speeding through the intersection and drivers who enter the intersection after the red-light
Intersection Safety Device

Background
Problem of Red-light Running and Speed

- RLR is a common cause of intersection collisions
- RLR collisions tend to result in right-angle collisions
- RLR occurs in 30-35% of signal phase cycles\(^1,2\)
- Drivers who are speeding are more likely to run a red-light


Problem of Red-light running and Speed

- Speeding increases the risk of collision as well as the severity of collisions
- At higher speeds there is less time to observe, react and maneuver to avoid collisions
- Due to increased kinetic energy, collisions severity increases at higher speeds
- In Edmonton 57% of all collisions and 72% of injury collisions occur at intersections
Background

RLC and ISD Previous Research

- Several studies have been conducted regarding RLC safety effectiveness, but few have been focused on ISD.
- RLC and ISD evaluations tend to focus on changes in overall collisions, severe, angle collisions and rear-end collisions.
- Most studies focus on intersection level changes, not approach level.
- Current research generally shows a reduction in angle collisions (6-46%), but an increase in rear-end collisions (9-44%).

Methodology

Data Description

- Traffic volumes were required for each year and missing data was extrapolated based on population changes.

Geometry Data

- Collected using google maps and city CAD database.
- Information included lane width and configuration, intersection size, etc.

Collision Data

- Collision history was collected for each site.
- Information included collision cause, severity and travel direction.
- Collision data was aggregated into 5 collision categories.

Collision Categories

- Total Collisions: Sum of PDO collisions and Severe collisions.
- Severe Collisions: All fatal and injury collisions.
- Property Damage Only (PDO) Collisions: Collisions which do not result in an injury or fatality.
- Rear-end Collisions: Collisions in which a leading vehicle is stuck by the following vehicle.
- Angle Collisions: Collisions involving at least two vehicles traveling in perpendicular directions.
Methodology

Methodology – Safety Performance Functions

Safety Performance Functions (SPF) are equations used to predict the number of collisions which will occur.

Variables include:
- Traffic volumes
- Number of lanes
- Average lane width
- Lane separation
- Other roadway characteristics

\[
\text{Collision rate} = \frac{A_{\text{observed}}}{A_{\text{predicted}}} = \exp(x_1 + x_2 + x_3 + \ldots)
\]

The SPF is created using data from a group of non-treated sites.

Reference intersections were used to create SPF.

These sites should be similar to treated sites.

A buffer was used to avoid affects from ISD spilling-over to reference sites.

Background

Before-and-After Safety Evaluation

- Empirical Bayes (EB) Before-and-After
  - Number of observed collisions compared to the number of expected collisions in the after period
  - Accounts for sources bias

- The expected number of collisions is a weighted sum of predicted and observed collisions:
  \[
  \text{Expected}_{\text{after}} = \text{EB} + \text{Pred}_{\text{after}} + \frac{1}{\text{EB}}/\text{Pred}_{\text{after}}
  \]

- A ratio of the predicted before and after collisions is used to determine the expected collisions after the treatment:
  \[
  \text{Expected}_{\text{after}} = \left(\frac{\text{Pred}_{\text{after}}}{\text{Pred}_{\text{before}}}\right) \times \text{Expected}_{\text{before}}
  \]
Background

Safety Evaluation Methods- Sources of Bias

Regression-to-the-Mean (RTM)

- The statistical phenomenon - collision numbers fluctuate
- Treatment sites are generally chosen due to high collision frequencies

Overestimating!

Background

Safety Evaluation Methods- Sources of Bias

Changing Collision Trends

- Changes in collision frequency due to general trends across all locations
- Example: population change or level of enforcement, etc.

Confounding Factors

- Temporary events or conditions that would impact collisions
- Examples include weather patterns, new collision countermeasures, etc.

Results & Discussion

- Intersection Level Results
- Approach Level Results
- Spillover Effects
- Site Selection Criteria
Results & Discussion

Intersection Level Analysis

<table>
<thead>
<tr>
<th></th>
<th>Total Collisions</th>
<th>Severe Collisions</th>
<th>PDO Collisions</th>
<th>Rear-End Collisions</th>
<th>Angle Collisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Collision Reduction</td>
<td>25.47*</td>
<td>3.99</td>
<td>6.35*</td>
<td>10.74*</td>
<td>33.44*</td>
</tr>
</tbody>
</table>

* Significant at 95% level

- Reductions were observed in all the collision categories
- Large reductions in Total and Angle collisions
- Unlike most other ISD or RLC studies, significant reductions were found in rear-end collisions

Approach Level Analysis

ISD cameras are not located on all intersection approaches
In this analysis only approaches with cameras are included

<table>
<thead>
<tr>
<th></th>
<th>Total Collisions</th>
<th>Severe Collisions</th>
<th>PDO Collisions</th>
<th>Rear-End Collisions</th>
<th>Angle Collisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collision Reduction</td>
<td>11.55*</td>
<td>3.06</td>
<td>11.74*</td>
<td>13.63*</td>
<td>43.06*</td>
</tr>
</tbody>
</table>

* Significant at 95% level

- Spillover effects are changes at untreated locations caused by the treatment
- If collisions have been reduced at non-ISD approaches it may indicate spillover effects
- Some previous studies of RLC and ISD cameras suggest that there are not strong spillover effects
### Results & Discussion

#### Approach Level Analysis – Spillover Effects

<table>
<thead>
<tr>
<th></th>
<th>ISD Approaches</th>
<th>Non-ISD Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Collisions</td>
<td>11.55*</td>
<td>53.22</td>
</tr>
<tr>
<td>Angle Collisions</td>
<td>3.36</td>
<td>82.33</td>
</tr>
<tr>
<td>Rear End Collisions</td>
<td>13.74*</td>
<td>29.06</td>
</tr>
<tr>
<td>Severe Collisions</td>
<td>13.42*</td>
<td>1.49</td>
</tr>
<tr>
<td>PDO Collisions</td>
<td>-6.29</td>
<td>92.68</td>
</tr>
</tbody>
</table>

* Significant at 95% level

- The reductions are much greater at the ISD equipped locations suggesting that spillover to other approaches may not occur at the approach level.
- There were significant reductions in angle collisions at all approaches, suggesting that spillover effects may occur for angle collisions.

#### Results & Discussion

##### Approach Level Analysis – Site Selection Criteria

- **Current ISD sites** are chosen based on a history of high collision frequency.
- **Collision reductions** were greatest at sites with high collision frequency (>15 yearly collisions).
- **No clear trend** between traffic volume and collision reduction was observed.
- **Significant reduction** in severe collisions at high collision locations.
- **Site selection criteria** is evaluated in two ways in order to identify factors which influence ISD success.

#### Site Selection Criteria

<table>
<thead>
<tr>
<th>Collision Frequency</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
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<tbody>
<tr>
<td>Collisions</td>
<td>6.33</td>
<td>7.71*</td>
<td>22.71*</td>
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<tr>
<td>PDO</td>
<td>3.36</td>
<td>1.99*</td>
<td>13.53</td>
</tr>
<tr>
<td>Traffic Volume</td>
<td>11.51</td>
<td>20.64*</td>
<td>34.64*</td>
</tr>
</tbody>
</table>

* Significant at 95% level
Results & Discussion

Site Selection – Intersection Characteristics

- Models were created to relate intersection characteristics to collision reductions
- Independent variables related to approach characteristics - number of lanes, speed limit, right turn separation.

<table>
<thead>
<tr>
<th></th>
<th>Total Collisions</th>
<th>Severe PDO</th>
<th>Rear End Collisions</th>
<th>Angle Collisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.98</td>
<td>-0.142</td>
<td>-0.135</td>
<td>-0.36</td>
</tr>
<tr>
<td>Number of Lanes</td>
<td>-0.142</td>
<td>-0.041</td>
<td>-0.031</td>
<td>-0.19</td>
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<tr>
<td>Speed Limit</td>
<td>0.041</td>
<td>0.045</td>
<td>0.031</td>
<td>0.018</td>
</tr>
<tr>
<td>Right Turn Separation</td>
<td>-</td>
<td>1.19</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Collision reductions were greater at approaches with more through lanes.

Results suggest reductions were greatest at sites with:
- Speed limits 60 km/hr
- Separated right turn lane
- >5 lanes

<table>
<thead>
<tr>
<th>Speed Limit</th>
<th>Right Turn Lane Separation</th>
<th>Number of Lanes</th>
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</thead>
<tbody>
<tr>
<td>50 km/hr</td>
<td>No</td>
<td>5</td>
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<tr>
<td>60 km/hr</td>
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<td>6</td>
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<td>70 km/hr</td>
<td>No</td>
<td>6</td>
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</tbody>
</table>

Total

| Angle       | 27.77                     | 46.21         | 46.21               | 27.77 |
|            | 20.50*                    | 49.27*        | 49.87               | 21.00 |

* Significant at 95% level

Results & Discussion

Site Selection – Intersection Characteristics

170 St & 87 Ave – Southbound Approach
- Average 15 collisions per year
- 6 lanes
- Separated right turn lane
- 60 km/hr speed limit

65% reduction in total collisions
Further ISD Benefits

- Further enforcement opportunity – right turn on red
- Diagnosis of problem behavior – It was discovered that vehicles in the 3rd lane had a higher proportion of red-light running so additional signal heads were added
- Collision investigations

Automated Mobile Speed Enforcement on Urban Arterial Roads

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City of Edmonton Office of Traffic Safety

Previous Works

<table>
<thead>
<tr>
<th>Study</th>
<th>Enforcement Program</th>
<th>Major Findings</th>
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<tbody>
<tr>
<td>Carnis &amp; Blais (2013)</td>
<td>French Speed Camera Program</td>
<td>21% reduction in fatality rate</td>
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<td></td>
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<td>Diminishing effects on injury collisions</td>
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</tbody>
</table>
Previous Works

• Results Summary
  – Consistent effectiveness of automated mobile enforcement
  – The results revealed 17% to 31% collision reductions
  – More reductions in fatal and injury collisions

Gaps in the Literature

• More focused on the system-wide collisions rather than segment-based collisions
• Deficiencies in methodology (RTM, traffic volume, trend, and other confounding factors)
• Little discussion on enforcement strategy and spillover effect on the opposite approach

DATA DESCRIPTION
Data Description

• Study Period: January 2005 – December 2012
• Road Segment (93 enforced 266 reference):
  – Deployment Hour
  – Traffic Counts (AADT)
  – Road Geometry Data
  – Midblock Collision Data

Data Description

• GIS Data Collection

Data Description

Deployment Hour

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<tr>
<th>Year</th>
<th>2005</th>
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<th>2007</th>
<th>2008</th>
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</tbody>
</table>

Before Period After Period
METHODOLOGY

Safety Performance Function (SPF)

- Generalized linear model (negative binomial)
- Model form:
  \[ \mu = V^b L^c \exp(\beta_1 + \beta_{\text{UNSD}} + \beta_{\text{Median}}) \]
  - \( V \) – AADT, \( L \) – Length, \( \text{UNSD} \) – unsignalized intersection density,
  \( \text{Median} \) – presence of median dummy
- Selection of reference group:
  - Arterial segments with similar AADT and collision
  - No enforcement and not adjacent to enforced segments
- Calibration: SAS GENMOD procedure
- GOF: scaled deviance and Pearson \( \chi^2 \)

Yearly Calibration Factor (YCF)

- Annual fluctuation confounding factors
  - Weather conditions, roadway improvement, general trend in safety, etc.
- Assumption
  - the impacts of the confounding factors on collision variation are similar for
    both the reference segments and the enforced segments.
- Calculation (by year by collision type)
  \[ YCF = \frac{\sum \text{Observed Collisions}}{\sum \text{Predicted Collisions}} \]
- Adjusted predicted number of collisions: \( \mu \cdot YCF \)
Empirical Bayes Method (EB)

- Step 1: expected number of collisions for before period
  \[ E_B = w \cdot \mu_a + (1 - w) \cdot \text{Obs}_a \]
- Step 2: expected number of collisions for after period
  \[ E_A = \left( \frac{\hat{\mu}_a}{\mu_a} \right) E_B \]
- Step 3: overall odds ratio of collision reduction
  \[ \theta = \frac{\sum N_i \cdot \sum E_A}{\sum \text{EVAR} \cdot \left( \sum E_A \right) / \left( \sum E_B \right)} \]

Methods Comparison

<table>
<thead>
<tr>
<th>Before-After Methods</th>
<th>Naïve</th>
<th>Comparison Group</th>
<th>Empirical Bayes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression-to-the-Mean Effect</td>
<td>☒</td>
<td>☒</td>
<td>☑</td>
</tr>
<tr>
<td>General Trend of road safety</td>
<td>☒</td>
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<td>☑</td>
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<tr>
<td>External Factors</td>
<td>☒</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Change in Traffic Volume</td>
<td>☒</td>
<td>☒</td>
<td>☑</td>
</tr>
</tbody>
</table>

RESULTS
SPF Estimation Results

- All the SPFs fit the data well
- Most parameters are statistically significant

<table>
<thead>
<tr>
<th>Source</th>
<th>Intercept</th>
<th>AADT</th>
<th>Length</th>
<th>UNSD</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Census</td>
<td>-10.25*</td>
<td>1.05*</td>
<td>0.44*</td>
<td>0.06*</td>
<td>-0.28*</td>
</tr>
<tr>
<td>PDO</td>
<td>-5.87*</td>
<td>0.74*</td>
<td>0.36*</td>
<td>0.07*</td>
<td>-0.32*</td>
</tr>
<tr>
<td>Total</td>
<td>-6.00*</td>
<td>0.78*</td>
<td>0.38*</td>
<td>0.07*</td>
<td>-0.31*</td>
</tr>
<tr>
<td>Speed-related</td>
<td>-6.48*</td>
<td>0.75*</td>
<td>0.40*</td>
<td>0.07*</td>
<td>-0.15*</td>
</tr>
<tr>
<td>Collision</td>
<td>-6.73*</td>
<td>0.81*</td>
<td>0.41*</td>
<td>0.06*</td>
<td>-0.18**</td>
</tr>
</tbody>
</table>

* Significant at 0.01 level  ** Significant at 0.05 level

Overall Evaluation

<table>
<thead>
<tr>
<th>Reduction Percentage by Collision Severity/Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Collision</td>
</tr>
<tr>
<td>20.1%</td>
</tr>
</tbody>
</table>

4/27/2016
Overall Evaluation

- Site Selection Criteria
  - Collision frequency
  - Collision rate
  - AADT
  Example: Total Collisions

- Deployment Hours
  - Total hours
  - Yearly average hours
  Example: Total Collisions

### Enforcement Strategy

- Continuous vs. Discontinuous Strategies

<table>
<thead>
<tr>
<th>ID</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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</tbody>
</table>

Reduction Percentage by Collision Severity/Type

![Bar chart showing reduction percentage by collision severity and type]
Spillover Effects

- Unenforced Adjacent Approach (39 pairs)

Spillover Effects

- Enforced vs. Unenforced Segments

Reduction Percentage by Collision Severity/Type

Spillover Effects

- Enforced Approach

Reduction Percentage by Collision Severity/Type
Spillover Effects

- Unenforced Adjacent Approach

Reduction Percentage by Collision Severity/Type

<table>
<thead>
<tr>
<th>Collision Severity/Type</th>
<th>Enforced</th>
<th>Unenforced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Collision</td>
<td>8.2%</td>
<td>8.2%</td>
</tr>
<tr>
<td>PDO Collision</td>
<td>4.5%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Angle Collision</td>
<td>11.1%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Rear-end Collision</td>
<td>14.6%</td>
<td>14.6%</td>
</tr>
<tr>
<td>Severe Collision</td>
<td>15.4%</td>
<td>15.4%</td>
</tr>
</tbody>
</table>

CONCLUSIONS

Conclusions

ISD Summary – Significant Collision Reductions in the following categories

- Intersection level
  - 14% Total collisions
  - 31% Angle collisions
  - 11% Rear-end collisions
- Approach level
  - 12% Total collisions
  - 41% Angle collisions
  - 14% Rear-end collisions
  - 29% Severe collisions locations with high collision frequency (>15)
Conclusions

ISD Summary – Site Selection

- Collision frequency was found to be successful as site selection criteria
- Traffic volume was not a recommended site selection criteria
- Intersection characteristics related to greater reductions at ISD approaches included: number of lanes, speed limit and right turn lanes

Conclusions

- 20% reduction in severe collisions and 15% reduction in total collisions
- Continuous strategy is able to achieve better results than discontinuous strategy
- 15% reduction in PDO collisions on adjacent unenforced segments

Conclusions

- Speed effects of enforcement
- Safety effects on other types of road
- Enforcement effectiveness models
- Drivers’ attitude towards enforcement
Thank You

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