MULTIMODAL INJURY RISK ANALYSIS OF ROAD USERS AT SIGNALIZED AND NON-SIGNALIZED INTERSECTIONS

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OUTLINE

• Background
• Literature review
• Research motivations
• Objectives
• Methodology
• Results
• Conclusion
• Limitations and future work
BACKGROUND

• Recent increase in modal share of walking and cycling

• Strategies to make roads safer for vulnerable road users
  • Installation and expansion of bicycle facilities, all-red phases for pedestrians, curb extensions, better marking, etc....)

• Despite the many efforts, road safety remains a major concern
LITERATURE

• Cyclist safety studies:
  • Most carried out in Europe and Asia
  • Focused on injuries at city or town level – not intersections

• Pedestrian safety studies:
  • Not as rare in North America
  • Focused on intersections

• Overall results for both modes – as traffic flows increase – injury occurrence increases
• Few attempts have been made to combine these into a multimodal approach
  • Are intersections which are safe for cyclists, dangerous for pedestrians or vehicles....?
Obtain a basis to compare safety between sites

Bayesian models - popular since safety measures and ranking criteria can be computed easily

Shortcomings:

Non-signalized intersections have not been studied

Studies have not looked at multiple road users

Bayesian methods to identify dangerous intersections for cyclists and pedestrians have not been used

Explanatory variables such as traffic controls, geometric design and built environment characteristics have not been considered
RESEARCH MOTIVATIONS

• Intersection – complex area where many interactions can occur between cyclists, motor-vehicles and pedestrians
  • 60% of total injuries (in Montreal)

• Prevent future accidents from occurring

• In the current literature there is a lack of:
  1. Systematic methods for collecting and integrating traffic exposure measures
  2. Studies implementing multimodal approaches to address urban mobility and safety

• Urgent need to combine 1 and 2 into a decision making tool
OBJECTIVES

For cyclists, pedestrians and motor-vehicles and at both signalized and non-signalized intersections:

1) Develop injury occurrence models
2) Estimate injury risk using a Bayesian approach
3) Carry out comparative analysis for flows, injuries and risk
4) Investigate the impact of motor-vehicle flows on cyclist and pedestrian safety
METHODOLOGY

• Bayesian modeling framework – simultaneously for injuries and flows
  • Injuries = function of:
    • Average annual daily cyclist or pedestrian traffic
    • Average annual daily motor-vehicle traffic flow
    • Geometric design and built environment characteristics
    • Delay or Level-of-service (LOS)
  
• Flow = function of:
  • The same or different geometric design and built environment characteristics
METHODOLOGY

• Two criteria used for comparing safety between modes and intersection types
  1. Expected injuries
     • Posterior mean from the Bayesian model results - $\theta$
  2. Injury risk (rate)
     • Posterior injury rate per million cyclists, pedestrians and motor-vehicles per unit time - $\bar{R}_{iY} = \bar{\theta}_{iY} \times 10^6 / 365 \cdot t_i \cdot Z_i$
SITE SELECTION

- Island of Montreal
- 647 signalized intersections &
- 435 non-signalized, selected since:
  1. recent count data is available
  2. counts carried out during the cycling season, when bicycle facilities are open
  3. Geometric design and built environment data have been collected
  4. the completion dates of bicycle facilities are known
DATA – TRAFFIC FLOW

- Manual cyclist, pedestrian and motor-vehicle flows

Can show similar maps for pedestrians and vehicles as well.
DATA - INJURY

- Cyclist, pedestrian and motor-vehicle injury data

Can show similar maps for pedestrians and vehicles as well.
DATA - INJURY

Signalized Intersections

Non-Signalized Intersections

Average Number of Cyclist/Pedestrian Injuries

Average Number of Cyclist/Pedestrian Injuries

Number of Motor-Vehicle Occupant Injuries

Number of Motor-Vehicle Occupant Injuries
DATA – GD AND TRAFFIC CONTROL

• Geometric design (GD) and traffic control characteristics for each intersection

Additional Intersection Attributes (not shown)
- Number of approaches
- Number of lanes
- Curb Extension
- Pedestrian phasing
- Presence of an arterial
- Presence and type of bicycle facilities
- Bus stops

Example of Signalized Intersection

Example of Non-Signalized Intersection
DATA – BUILT ENVIRONMENT

- Built environment data
# Results – Injury Models

<table>
<thead>
<tr>
<th>Signalized Intersections</th>
<th>Non-Signalized Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a)</strong> CYCLIST</td>
<td><strong>b)</strong></td>
</tr>
<tr>
<td>Variable</td>
<td>Coef.</td>
</tr>
<tr>
<td>Ln bicycle flows</td>
<td>0.869</td>
</tr>
<tr>
<td>Ln mv right turn flows</td>
<td>0.240</td>
</tr>
<tr>
<td>Ln mv left turn flows</td>
<td>0.185</td>
</tr>
<tr>
<td>Presence of bus stops</td>
<td>0.519</td>
</tr>
<tr>
<td>Total crosswalk length</td>
<td>0.009</td>
</tr>
<tr>
<td>Raised median</td>
<td>-0.351</td>
</tr>
<tr>
<td>Constant</td>
<td>-10.08</td>
</tr>
</tbody>
</table>

| **c)** PEDESTRIAN         | **d)**                      |
| Variable                 | Coef.  | Credible Interval | Variable | Coef.  | Credible Interval |
| Ln pedestrian flows      | 0.811  | 0.754 - 0.882    | Ln pedestrian flows | 0.702  | 0.286 - 1.094    |
| Ln mv flows              | 0.318  | 0.300 - 0.330    | Ln mv flows        | 0.416  | 0.039 - 0.783    |
| All-red phase            | -0.389 | -0.940 - 0.148   |                      |        |                  |
| Half-red phase           | -0.360 | -0.674 - 0.045   |                      |        |                  |
| Number of lanes          | 0.126  | 0.094 - 0.164    |                      |        |                  |
| Commercial entrances/exit| 0.068  | -0.010 - 0.145   |                      |        |                  |
| Constant                 | -3.96  | -4.72 - 3.46     | Constant            | 9.88   | 6.35 - 12.81     |

| **e)** MOTOR-VEHICLE      | **f)**                      |
| Variable                 | Coef.  | Credible Interval | Variable | Coef.  | Credible Interval |
| Ln mv right turn flows   | 0.174  | 0.148 - 0.212    | Ln mv right turn flows | 0.166  | -0.103 - 0.399   |
| Ln mv left turn flows    | 0.163  | 0.121 - 0.195    | Ln mv left turn flows | 0.129  | -0.030 - 0.247   |
| Ln mv through flows      | 0.263  | 0.239 - 0.282    | Ln mv through flows  | 0.951  | 0.7868 - 1.103   |
| Presence of bus stops    | 0.661  | 0.409 - 0.897    |                      |        |                  |
| Three approaches         | -0.350 | -0.626 - 0.081   |                      |        |                  |
| Constant                 | -4.63  | -4.74 - 4.43     | Constant            | -11.70 | -13.00 - 9.85    |

*mv = motor-vehicle*
RESULTS – INJURY

**Signalized Intersections**
- Motor-Vehicle: 70% (72.1%)
- Pedestrian: 20% (18.0%)
- Cyclist: 10% (9.9%)

**Non-Signalized Intersections**
- Motor-Vehicle: 58% (63.2%)
- Pedestrian: 14% (15.7%)
- Cyclist: 28% (21.1%)
RESULTS - RISK

Signalized Intersections

- **Bicycle**
- **Pedestrian**
- **Vehicle**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Number of Intersections</th>
</tr>
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<tr>
<td>&lt;0.25</td>
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<tr>
<td>0.25-0.5</td>
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<tr>
<td>0.5-0.75</td>
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<tr>
<td>0.75-1</td>
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<td>1.25-1.5</td>
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<tr>
<td>1.5-1.75</td>
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<td>1.75-2</td>
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<tr>
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<tr>
<td>2.75-3</td>
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<tr>
<td>&gt;3</td>
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</table>
RESULTS – RISK

Signalized Intersections

Non-Signalized Intersections
CONCLUSION

- Importance of motor-vehicle traffic – in total and turning movements – on injury occurrence
  - Of all modes
  - Both facility types
- Also, at signalized intersections:
  - For cyclists – crosswalk length, raised median and bus stops
  - For pedestrians – number of lanes, all-red and half-red phases, commercial entrances/exits
  - For motor-vehicles – bus stops, three vs four approaches
- Number of injuries and risk are higher at signalized than at non-signalized intersections
LIMITATIONS AND FUTURE WORK

• Improve multimodal approach – simultaneous model

• Investigate effect of correlation among injury outcomes

• Require larger sample of non-signalized intersections

• Repeat analysis with police report accident data – validate results
THANK YOU!

References: