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….?

LITERATURE

- 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

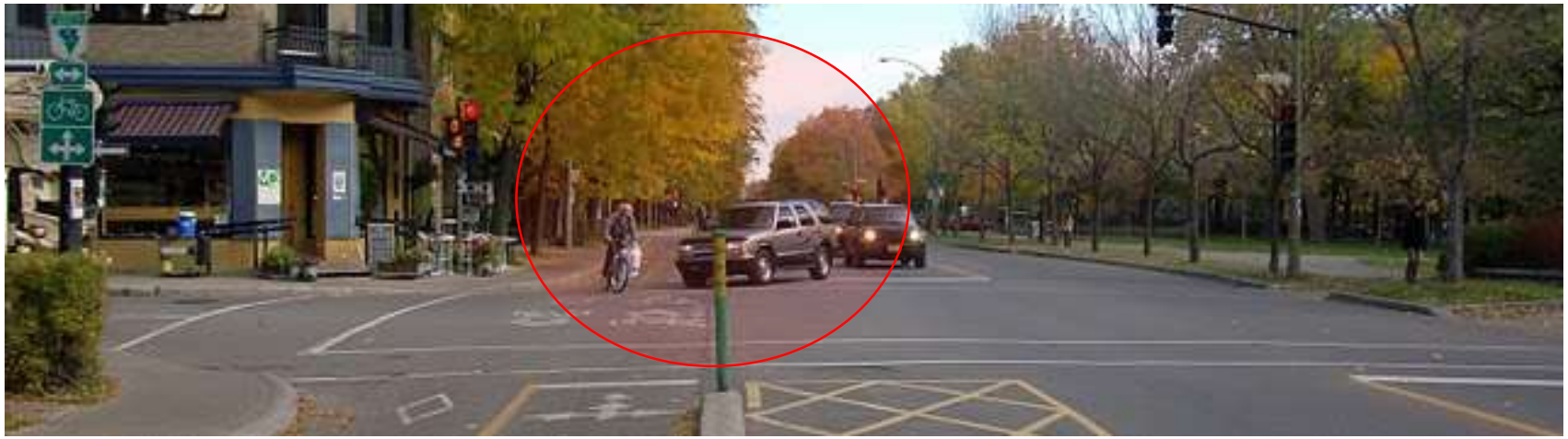
2) Estimate injury risk using a Bayesian approach

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 - θ
  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

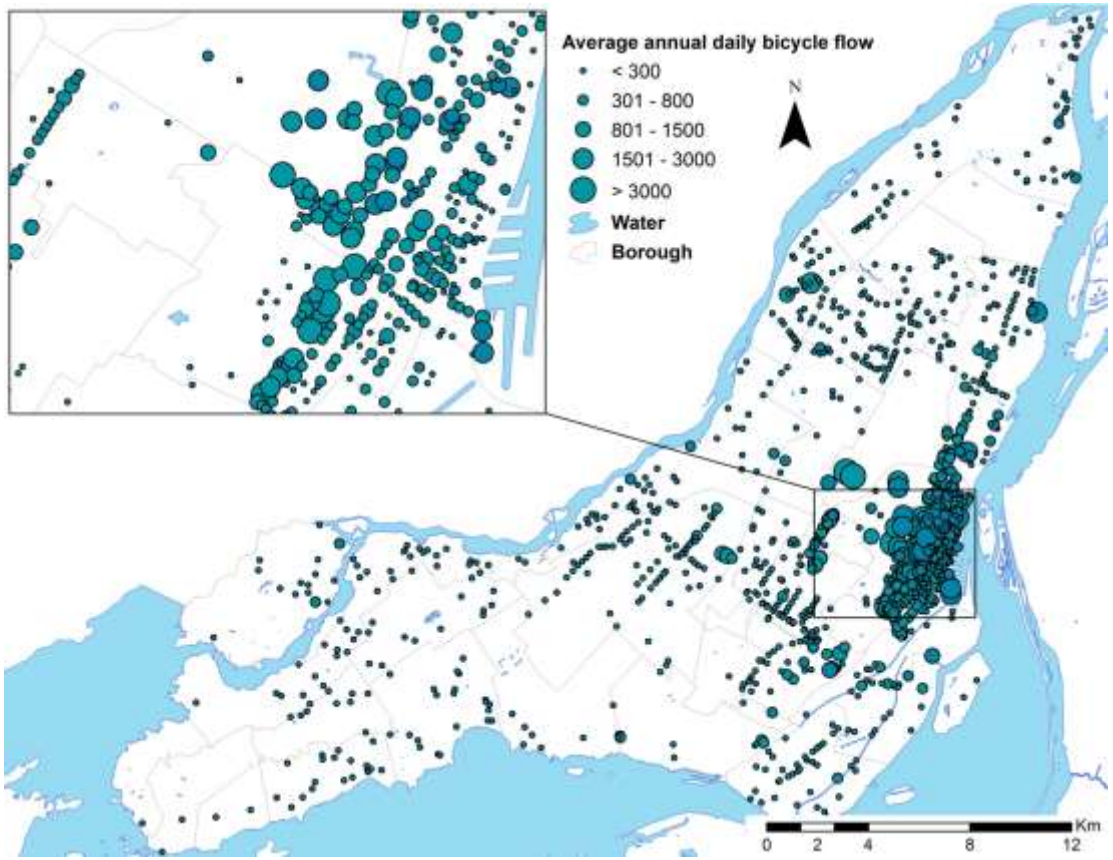
- Island of Montreal

- 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 know

DATA – TRAFFIC FLOW

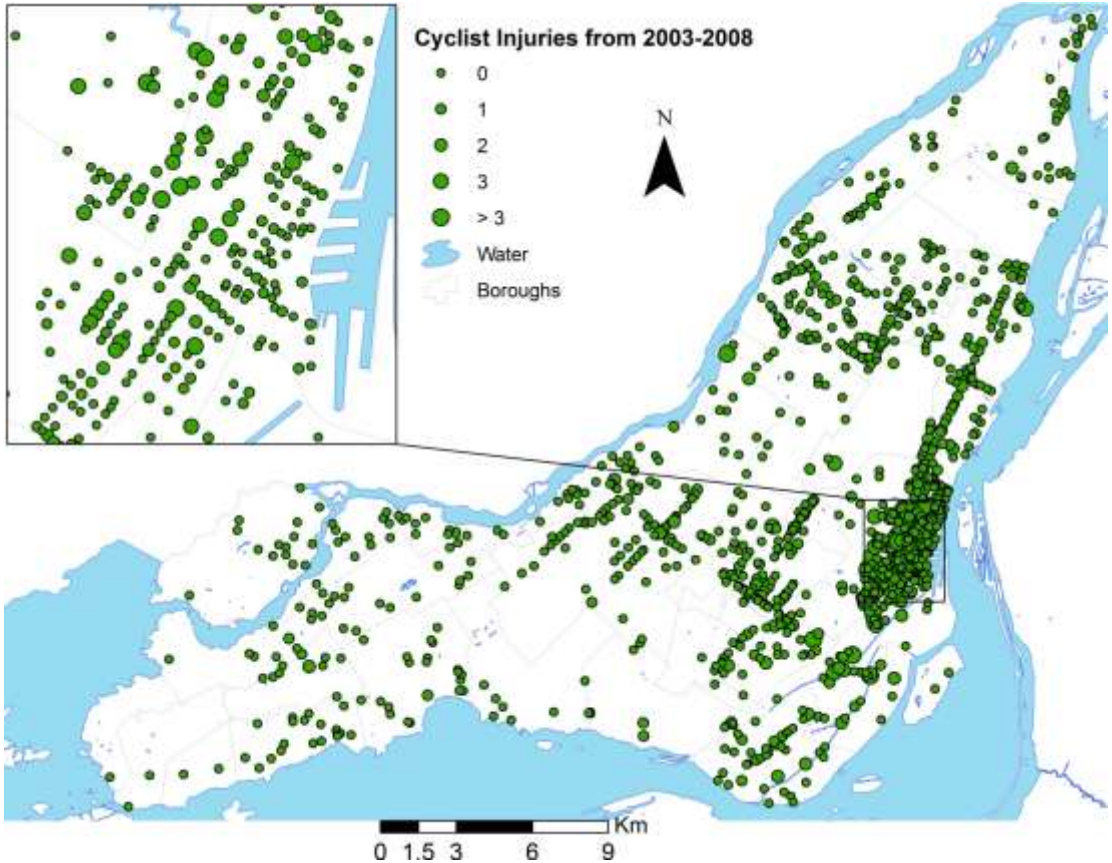
- Manual cyclist, pedestrian and motor-vehicle flows



Can show similar maps for pedestrians and vehicles as well.

DATA - INJURY

- Cyclist, pedestrian and motor-vehicle injury data



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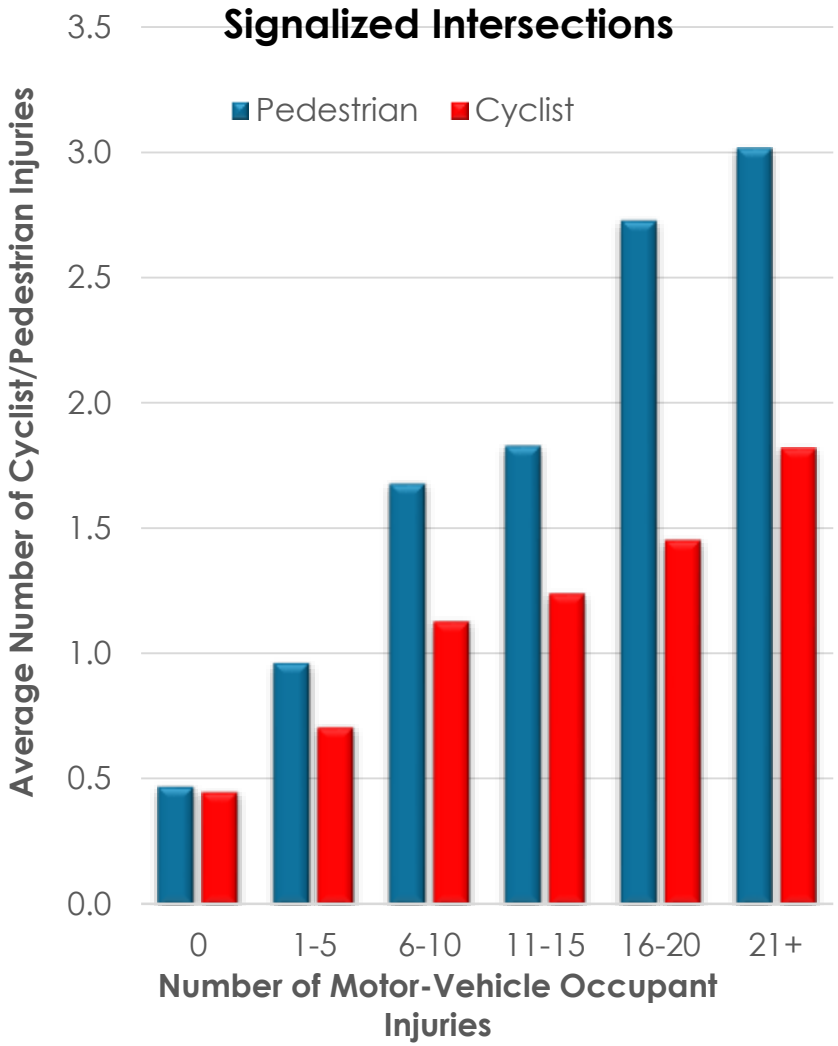
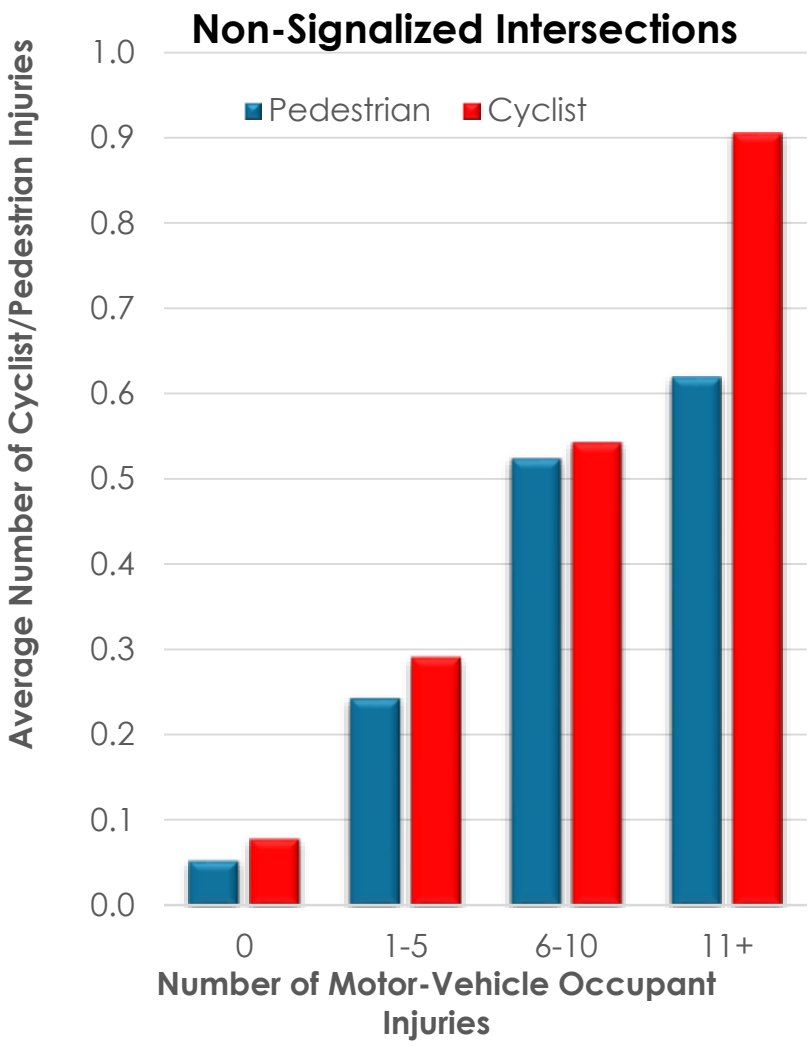
DATA - INJURY


Signalized Intersections
Pedestrian
Cyclist
Average Number of Cyclist/Pedestrian Injuries
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1-5
6-10
11-15
16-20
21+
Number of Motor-Vehicle Occupant Injuries


Non-Signalized Intersections
Pedestrian
Cyclist
Average Number of Cyclist/Pedestrian Injuries
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1-5
6-10
11+
Number of Motor-Vehicle Occupant Injuries

DATA – GD AND TRAFFIC CONTROL

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

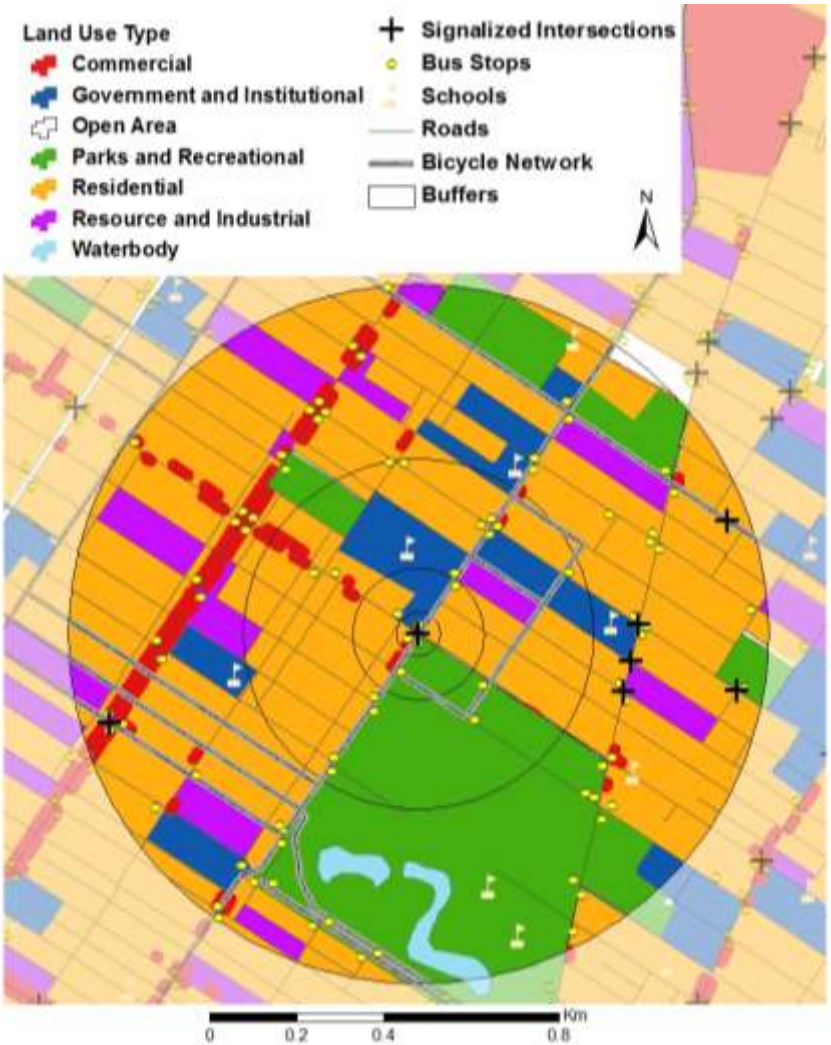
Additional Intersection Attributes (not shown)
Number of approaches
Number of lanes
Curb Extension
Pedestrian phasing
Presence of an arterial
Presence and type of bicycle facilities
Bus stops

Example of Signalized Intersection

Example of Non-Signalized Intersection

DATA – BUILT ENVIRONMENT

- Built environment data



RESULTS – INJURY MODELS

Signalized Intersections				Non-Signalized Intersections			
a)		**CYCLIST**		**b)**			
Variable	Coef.	Credible Interval		Variable	Coef.	Credible Interval	
Ln bicycle flows	0.869	0.765	1.013	Ln bicycle flows	0.748	0.447	0.998
Ln mv right turn flows	0.240	0.153	0.307	Ln traffic flows	0.261	0.057	0.415
Ln mv left turn flows	0.185	0.106	0.279	Total number of lanes	0.192	-0.020	0.386
Presence of bus stops	0.519	0.196	0.842				
Total crosswalk length	0.009	0.004	0.014				
Raised median	-0.351	-0.640	-0.037				
Constant	-10.08	-10.66	-9.58	Constant	-17.52	-18.48	-16.67

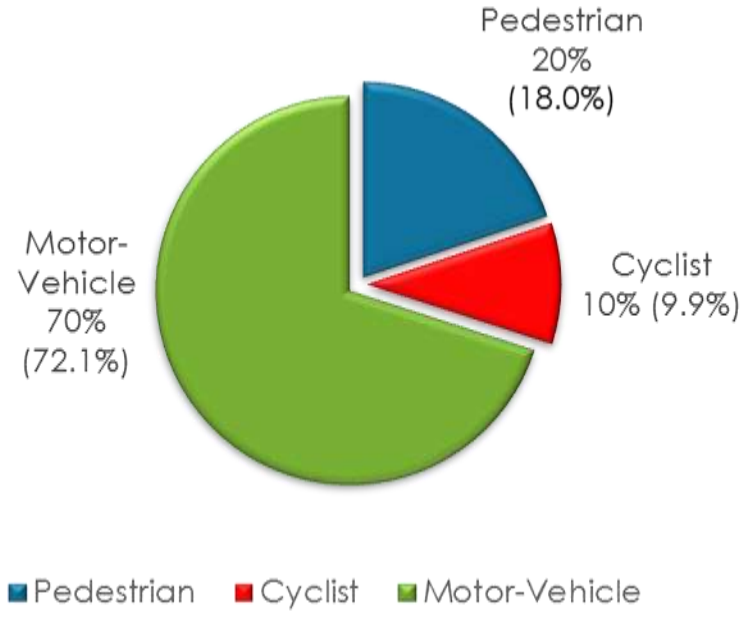
c)		**PEDESTRIAN**		**d)**			
Variable	Coef.	Credible Interval		Variable	Coef.	Credible Interval	
Ln pedestrian flows	0.811	0.754	0.882	Ln pedestrian flows	0.702	0.286	1.094
Ln mv flows	0.318	0.300	0.330	Ln mv flows	0.416	0.039	0.783
All-red phase	-0.389	-0.940	0.148				
Half-red phase	-0.360	-0.674	-0.045				
Number of lanes	0.126	0.094	0.164				
Commercial entrances/exits	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

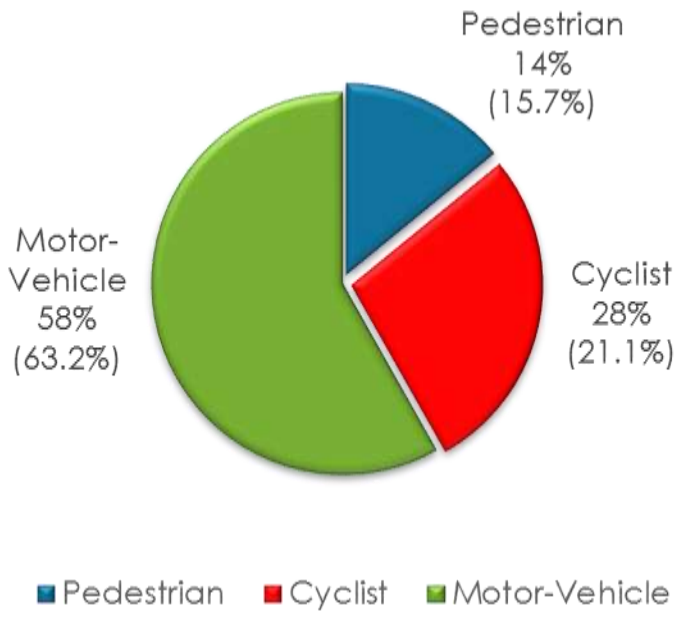
mv = motor-vehicle

RESULTS – INJURY

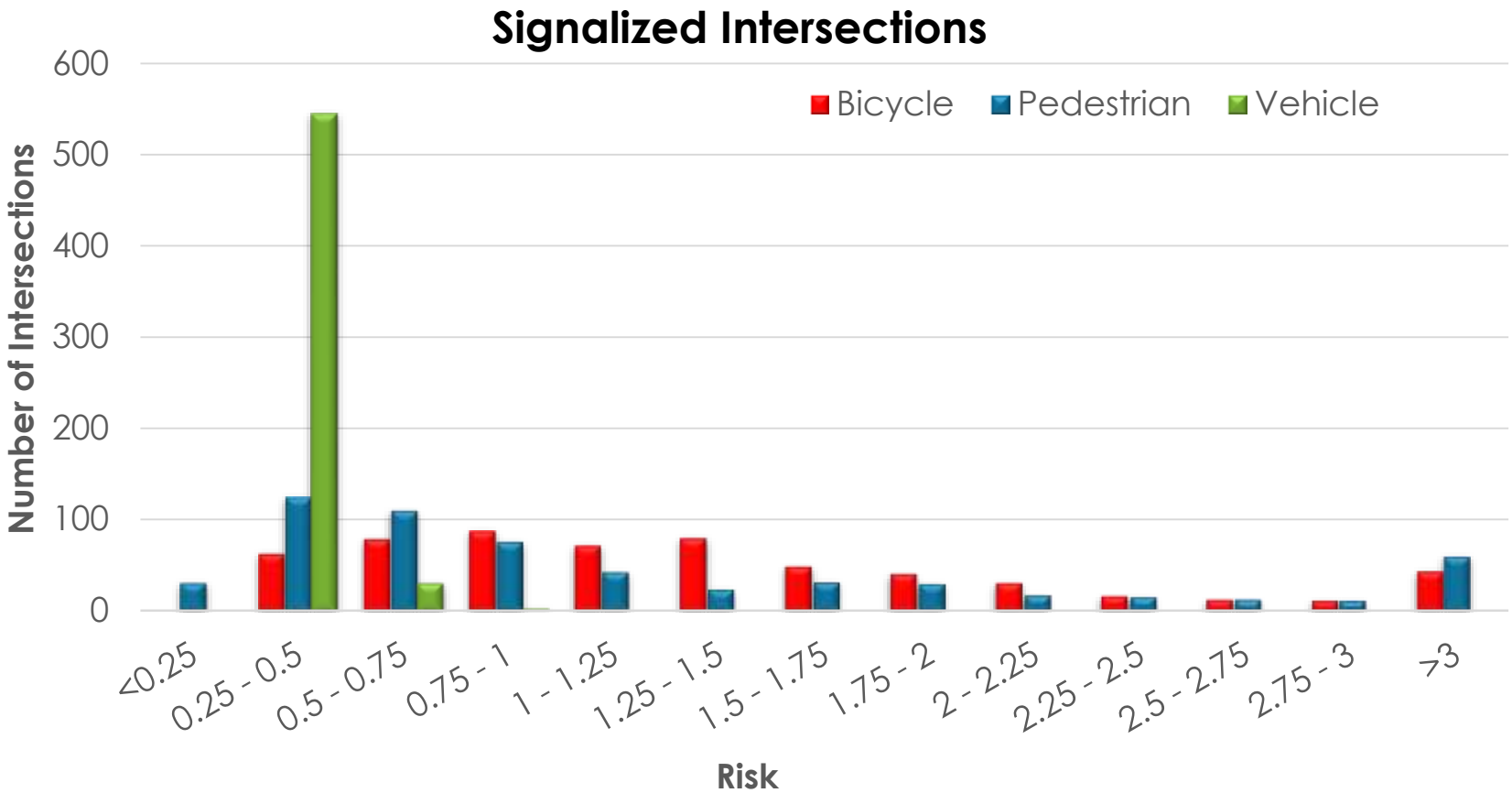
Signalized Intersections



Non-Signalized Intersections

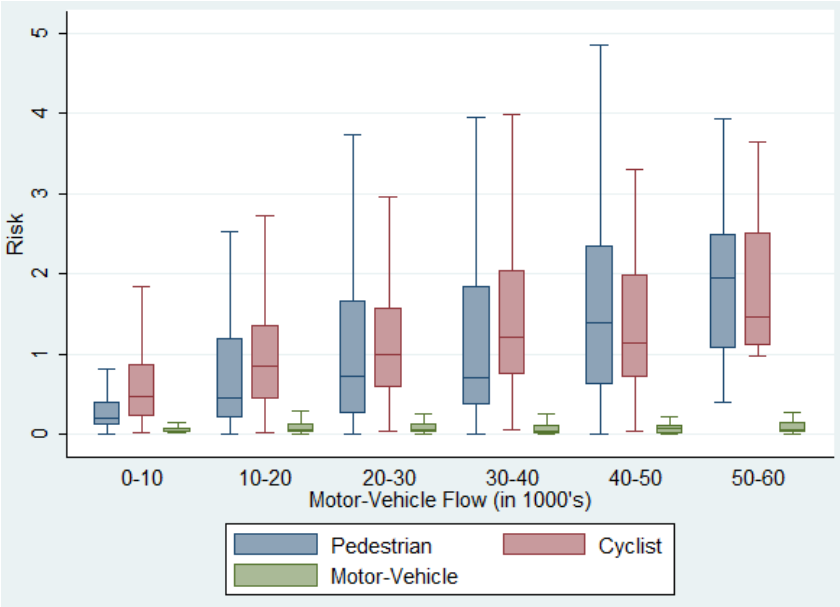


RESULTS - RISK

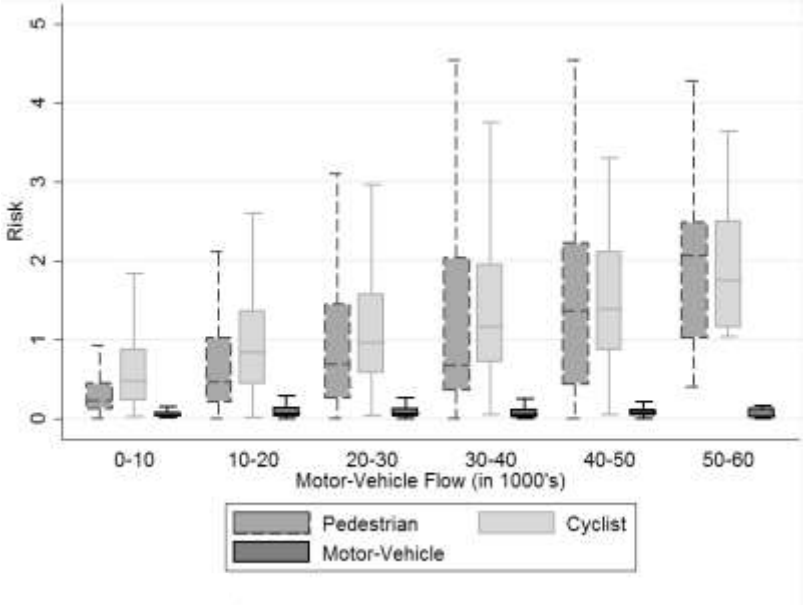


RESULTS – RISK

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!

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