iCSC International Cycling Safety Conference

6th Annual International Cycling Safety Conference
21-22 September 2017, Davis, California, USA

How does Bicycle Level of Traffic Stress Correlate with Reported Bicycle Crashes? A Geospatial and Mixed Logit Analysis

C. Chen[a], J. Anderson[b], H. Wang[c], R. Vogt[d], S. Hernández[e]

[a]Graduate Research Assistant
Oregon State University
101 Kearney Hall, Corvallis, OR 97331
Email: chenc4@oregonstate.edu

[b]Graduate Research Assistant
Oregon State University
101 Kearney Hall, Corvallis, OR 97331
Email: anderjas@oregonstate.edu

[c]Ph.D. Assistant Professor
Oregon State University
101 Kearney Hall, Corvallis, OR 97331
Email: haizhong.wang@oregonstate.edu

[d]Graduate Research Assistant
Oregon State University
101 Kearney Hall, Corvallis, OR 97331
Email: rachel.vogt@lifetime.oregonstate.edu

[e]Ph.D. Assistant Professor
Oregon State University
101 Kearney Hall, Corvallis, OR 97331
Email: Sal.Hernandez@oregonstate.edu

Keywords: bicycle safety, bicycle level of traffic stress, mixed logit, Geospatial analysis.

1 INTRODUCTION

Bicycle riding is on the rise in Oregon and the U.S.; however, bicycle fatalities have steadily increased since 2005 [1, 2]. While bike fatalities make up a small share of total traffic deaths, bicyclists are at higher risk of severe injury or death due to MV collisions than motorists. Yet despite the dangers, individuals are increasingly choosing to bike throughout the country and especially in the Pacific Northwest [3]. These national and local bicycle fatality trends is the major motive that Oregon has identified bicycle crashes as a primary focus area for investing in safety and infrastructure funding. However, engineers and planners face three interrelated challenges when conducting safety or planning analysis for bicyclists: 1) insufficient data about bicycle crashes; 2) lack of bicycle volume data on a network scale; 3) and the lack of tools to analyze safety improvement and bicycle planning applications [4]. Transportation agencies across the nation are experiencing an increase in bicycle ridership and need efficient tools that can improve bicycle safety while staying within limited budgets. One such method includes the level of traffic stress (LTS) criteria proposed by Mekuria et al. [5], which is primarily used to predict how various facility improvements will impact connectivity. Although this method is starting to become more commonly used among transportation agencies, it has not been used exclusively for safety purposes.

To fill this gap, this study uses crash data over a 10 year span for 4 cities in New Hampshire (Concord, Manchester, Nashua, Portmouth) to determine the geospatial and statistical relationship between bicycle level of traffic stress (BLTS) and bicycle crashes. This research will show that LTS models can serve as an alternative method for bicycle safety and planning analysis. There are two main goals for this paper:

1. Determine the correlation between high/low stress levels and high/low crash severity;
2. Determine if BLTS stress levels can be used as a proxy for safety risk evaluation.

By using a stress level analysis to aid in predicting where crashes may occur, communities can allocate funds more effectively for infrastructure safety improvements.

2 METHODOLOGY

Geospatial analysis was conducted in ArcGIS® to visualize the correlation between BLTS and crash severity. Combining crash data and BLTS data, a mixed logit modeling framework was applied to statistically identify correlations between crash/BLTS factors and crash severity. In an attempt to capture the unobserved factors (unobserved heterogeneity) present in most crash data (e.g., cyclist behavior under high/low levels of stress), the mixed logit model is represented as [6]:

$$P_n(i|\emptyset) = \int_x \frac{e^{\beta_i X_{in}}}{\sum_{\forall I} e^{\beta_i X_{in}}} f(\beta_i|\emptyset) d\beta$$

where $P_n(i|\emptyset)$ is the weighted outcome probability of injury severity i conditional on $f(\beta_i|\emptyset)$; $f(\beta_i|\emptyset)$ is the density function of β with distributional parameter $\emptyset$; β_i is a vector of estimable parameters; X_{in} is a vector of explanatory variables (e.g. level of traffic stress, roadway characteristics, crash characteristics, etc.).

Marginal effects are computed to determine the effect of an explanatory variable on the outcome probability of an injury severity. Log-likelihood ratio test [6] was used to determine the significance of the log-likelihood values between the fixed- and random-parameters models.

3 RESULTS AND CONCLUSION

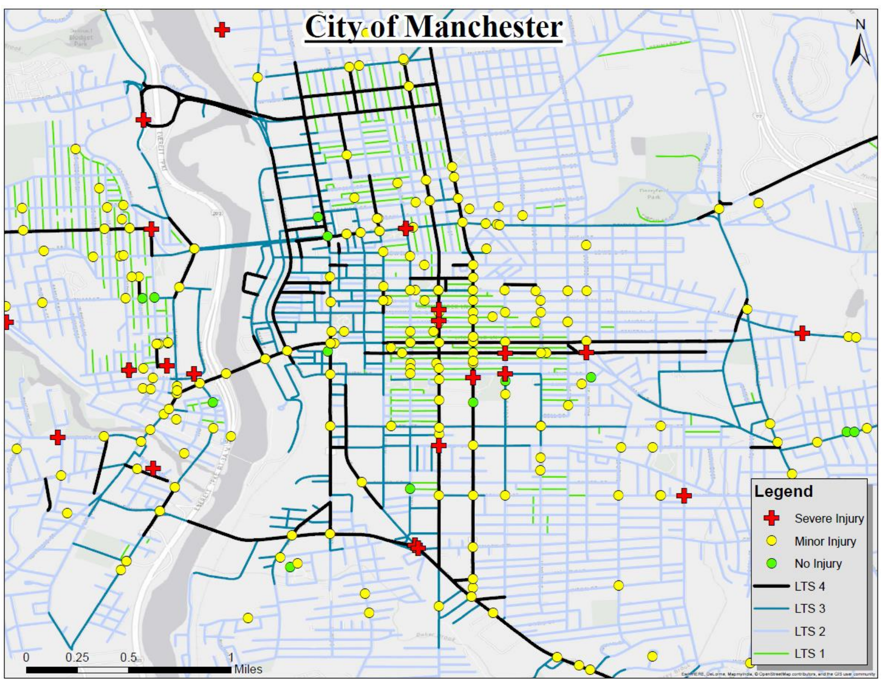

Figure 1, Spatial correlation between crash severities and BLTS

A mixed logit model was applied utilizing crash data from the four cities seen, and best fit model results are summarized in Table 1. BLTS 3 is significant for no/possible injury and marginal effects indicate that BLTS 3 increases the probability of no injury by 0.026, but decrease the probability of minor injury and severe injury. In addition, BLTS 4 is significant and increases the likelihood of no injury, but decreases the likelihood of minor injury. Similar results can be found in figure 1 which demonstrates the correlation between crashes severities and BLTS in City of Manchester (more results can be found in full paper). The estimated parameter for BLTS 4 was also found to be random in the minor injury severity function (heterogeneous across crash observations). A possible reason may stem from the different behaviors of bicyclists riding on segments with higher BLTS (e.g., bicyclists may react differently depending on their bicycle skills). Generally, the results of the model suggest that a high level of BLTS is correlated with no/possible injury. This conclusion, being opposite to intuition, suggests that higher levels of BLTS may encourage bicyclists to ride more cautiously when compared to riding on lower levels of BLTS. These findings also suggest that the definition of BLTS be revisited in order to be used as a proxy for future safety risk evaluation. Although this research is near completion, the BLTS data provides several avenues for future work.

Table 1: Best Fit Mixed Logit Resutls and Marginal Effects

			Marginal Effects		
Variable	Coefficient	t-statistic	No Injury	Minor Injury	Severe Injury
No/Possible Injury					
Constant	-1.12	-3.99			
Posted Speed Limit (1 if Greater Than 30MPH, 0 Otherwise)	0.70	1.78	0.012	-0.011	-0.001
Crash Location (1 if Along Roadway, 0 Otherwise	0.48	1.85	0.020	-0.017	-0.002
AADT (1 if Between 5,000 and 10,000, 0 Otherwise)	-0.80	-1.85	-0.008	0.005	0.003
(Standard Deviation of Normally Distributed Parameter)	*(1.43)*	*(2.13)*			
Level of Traffic Stress (1 if LTS 3, 0 Otherwise)	0.52	2.03	0.026	-0.023	-0.003
Minor Injury					
City (1 if Manchester, 0 Otherwise	-0.38	-1.71	0.165	-0.172	0.006
Road Configuration (1 if Divided Highway, 0 Otherwise)	-0.97	-2.83	0.017	-0.021	0.004
Road Geometrics (1 if Straight and Level, 0 Otherwise)	0.56	2.23	-0.058	0.072	-0.014
Roadway Width (1 if 30 Feet, 0 Otherwise)	-0.13	-0.33	0.016	-0.020	0.004
(Standard Deviation of Normally Distributed Parameter)	*(2.42)*	*(2.77)*			
Traffic Control Device (1 if Traffic Signal, 0 Otherwise)	0.36	1.32	-0.010	0.013	-0.003
Level of Traffic Stress (1 if LTS 4, 0 Otherwise)	-0.20	-0.67	0.019	-0.022	0.004
(Standard Deviation of Normally Distributed Parameter)	*(1.09)*	*(1.83)*			
Severe Injury					
Year Crash Occurred (1 if Before 2005, 0 Otherwise)	0.11	0.20	-0.010	-0.019	0.030
(Standard Deviation of Normally Distributed Parameter)	*(1.37)*	*(2.42)*			
Presence of Bike Lane (1 if No Bike Lane, 0 Otherwise)	-2.03	-4.23	0.031	0.044	-0.075
Road Direction (1 if Two-Way Road, 0 Otherwise)	1.08	2.38	-0.015	-0.024	0.039
Time-Of-Day (1 if Between 9:00PM and 6:00AM, 0 Otherwise)	1.07	2.02	-0.003	-0.005	0.008
Model Statistics					
Number of Observations	628				
Log-Likelihood at Zero	-518.04				
Log-Likelihood at Convergence	-486.84				
McFadden Psuedo R^2	0.06				

REFERENCES

[1] NHTSA, "Traffic Safety Facts," 2016.

[2] National Highway Traffic Safety Adminstriation and NHTSA, "TRAFFIC SAFETY FACTS 2012 Data," 2014.

[3] ABW, "Bicyclin and Walking in the United Stats 2014 Benchmarking Report," *Alliance Biking Walk.*, 2014.

[4] M. Lowry and D. Callister, "Using Bicycle Level of Service to Assess Community-wide Bikeability," *91st Annu. Meet. …*, pp. 1–15, 2012.

[5] M. C. Mekuria, P. G. Furth, and H. Nixon, "Loss-Stress Bicycling and Network Connectivity," *Mineta Transp. Inst. Rep. 11-19*, p. 68, 2012.

[6] F. L. Washington, S.P. and Karlaftis, M.G. and Mannering, *Statistical and Econometric Methods for Transportation Data Analysis 2nd ed.* Boca Raton: Chapman and Hall/CRC., 2011.