Macro Safety Analysis for Non-motorized Vehicles
Based on Roadway and Safety Education Improvement

Zhiceng Dai, Xuesong Wang, Wenbin Luo
Tongji University, China

ABSTRACT

Due to differences between crash location and the locations of the crashes-involved road users’ residences, traditional macro-safety analysis strategy could be inefficient when comprehensive improvements such as traffic safety education programs are considered. This paper:

• Proposing a new analysis strategy of separately aggregating crashes for roadway engineering improvement and road users for education improvement
• Collecting non-motorized crashes, crash-involved road users, roadway, socioeconomic and land use characteristics from 213 sub-districts in Shanghai
• Developing a multivariate Poisson lognormal conditional autoregressive (CAR) model as prediction model due to correlation between the location of the crashes and the residence of the involved road users
• Applying potential for safety improvement (PSI) to identify hot zones for engineering and education improvement respectively
• Developing False Positive (FP) and False Negative (FN) indexes to identify the differences of the hot-zone distributions quantitatively

The purpose of this study is to find the most appropriate strategy to apply effective roadway and safety education countermeasures for safety improvement.

INDEPENDENT VARIABLES:
• Roadway network data, including information on road type (e.g., highway, street) and intersections, was obtained from the Shanghai traffic police.
• Socioeconomic influence was represented by registered population.
• Land use characteristics were represented by area, area type and number of metro stations

DEPENDENT VARIABLES:
• The location and road user residence for each crash were precisely located on the map by longitude and latitude, and the numbers of each were gathered and counted in each sub-district using ArcGIS software.
• The two dependent variables were divided into two severity levels, fatal and injury crashes (FI) and property damage only crashes (PDO) for analysis of correlation between severity levels.

STATISTICAL MODELING

Macro-Level Safety Model:
A Bayesian multivariate Poisson-lognormal conditional autoregressive model was developed. The framework of the Bayesian inference was as follows:

\[ \psi(i, j) \sim \text{Poisson} \left( \mu(i, j) \right) \]

The Poisson-lognormal model assumes that the dependent variable \( \psi(i, j) \) follows the Poisson distribution as follows:

\[ \psi(i, j) \sim \text{Poisson} \left( \mu(i, j) \right) \]

The logit was used as a function to link the expected value of \( \psi(i, j) \) with independent variables as follows:

\[ \log(\mu(i, j)) = \eta(i, j) = X(i, j) \beta + \nu(i) + \phi_j \]

\( \nu(i) \) and \( \phi_j \) denote the unobserved random effects from sub-district \( i \) and subject variable \( k \), and follow the multivariate normal distribution.

The proximity matrix \( W \) with entry \( w_{ij} \) indicates the spatial relationship between unit \( i \) and unit \( j \):

\[ w_{ij} = \begin{cases} 1 & \text{if } \{i, j\} \in E \text{ and } d_{ij} \leq d_{C} \text{ or } j = i \ 0 & \text{otherwise} \end{cases} \]

The conditional distribution of \( \psi(i, j) \) and \( \phi_j \) turned out to be a normal distribution (\( \psi(i, j) \) is the set of \( \psi(i, j) \)):

\[ \psi(i, j) \sim N \left( \mu(i, j), \sigma^2 \right) \]

The estimation process used the Bayesian estimation approach implementing the Markov Chain Monte Carlo (MCMC) algorithm in the open source software WinBUGS to conduct estimation. In the process of model calibration, two MCMC chains of 40,000 iterations were obtained, with the first 5,000 iterations discarded as burn-in.

Analysis of Results:
Roadway characteristics had similar effects on both crashes and crash-involved road users, but the land use characteristics had different influence towards the studied subjects
The street length of Levels 1-2 was negatively associated with the studied subjects, while the length of Levels 3-4 streets had an opposite safety effect, probably because Levels 1-2 streets were more crowded and Levels 3-4 streets were more open
Urban area type was found to be positively associated with FI crashes and involved road users but negatively associated with PDO crashes and involved road users, probably because they are likely to be more mixed traffic composition in urban areas that can pose a higher risk for serious crashes

POTENTIAL SAFETY IMPROVEMENT:
Potential Safety Improvement (PSI) refers to the difference between the expected and predicted counts of crashes (as crash-involved road users). PSI for the four subjects (FI crashes, PDO crashes, FI road users, and PDO road users) were calculated using the macro-level model
Hot zones (FI) were identified as sub-districts with top 10% PSI of values
Warm zones (W) were identified as having PSIs greater than zero, but not in the top 10%
Cold zones (C) were the sub-districts with PSIs lower than zero

SUMMARY AND CONCLUSIONS

This study proposed a new strategy for macro safety analysis based on comprehensive improvement countermeasures, which was utilized to further improve this study by separately aggregating crashes for roadway engineering improvement, and crash-involved road users for traffic safety education improvement.
A Bayesian multivariate Poisson-lognormal conditional autoregressive (CAR) model was developed to examine the relationships between regional characteristics and traffic safety
Integrated identification results showed significant differences between engineering hot zones and education hot zones
A False positive index and a False negative index were further developed to more accurately identify the differences, which indicated that nearly half of the identified hot zones were inconsistent in unnecessarily prioritizing either engineering or education improvement
Due to the separate analyses of crashes and crash-involved road users, the new analysis strategy proposed in this study is thus far more practical for safety improvement. Conclusions drawn from this study suggest a different approach to provide effective traffic safety for local administrators and transportation planners and provide a comprehensive understanding of hot zones for a more effective use of limited resources.