REPORT OF RESEARCH RESULTS

A. Title

Examining the Risk of the Near Misses for Light Rail Transit Using Multinomial-Generalized Poisson Models

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C. Summary

Light rail systems are vital to urban transportation, valued for reliability and convenience. However, operating in mixed-traffic environments — especially at intersections — raises collision risks. Near-miss events, sharing similar causes with crashes, serve as key indicators for safety assessment. This study analyzes 4,350 near-miss events recorded on the Kaohsiung Light Rail from April 2024 to March 2025, exploring their frequency and influencing factors.

A Zero-Inflated Multivariate Generalized Poisson (ZMGP) model is employed to analyze event data derived from onboard video recordings of light rail vehicles. Addressing the limitations of previous research that primarily focused on crash data, this study leverages the abundance of near-miss events to enhance the robustness and sensitivity of risk assessments. The ZMGP model was adopted to accommodate excess structural zeros and heterogeneity across multiple levels of driver involvement, leveraging its multivariate and zero-inflated structure.

The results reveal significant variations and cross-level interactions among near-miss events of varying involvement levels (e.g., horn usage, deceleration, emergency braking). Furthermore, by integrating ZMGP simulation outputs with Geographic Information Systems, this study successfully identified spatial hotspots and evaluated the effectiveness of enforcement equipment in reducing near-miss incidents.

This study offers a multilayered risk assessment framework, addressing gaps in crash-based analyses and supporting intersection design, enforcement, and driver training to enhance light rail safety in mixed-traffic environments.

D. Aim of Research

This study has three key research objectives:

1. Identify potential risk factors associated with the occurrence of near-miss events, with a particular focus on intersection geometry, driver behavior, and traffic violations.

      Through empirical data collection and statistical modeling, the study aims to examine whether specific environmental and spatial characteristics significantly influence the likelihood of near-miss incidents, thereby identifying critical risk contributors and high-risk locations.

2. Evaluate the function of near-miss events as potential precursors to accidents, by analyzing the distribution and determinants of varying levels of event involvement within the Kaohsiung Light Rail Transit (KLRT) system. Based on the analytical results, this study seeks to propose targeted improvement strategies, such as engineering modifications, behavioral interventions, or early warning systems, to reduce the frequency and involvement level of such incidents.

3. Integrate statistical modeling with Geographic Information Systems (GIS) for risk hotspot simulation and improvement benefit evaluation, by applying a Zero-Inflated Multivariate Generalized Poisson (ZMGP) model to estimate the expected frequency and involvement structure of near-miss events at each intersection.

      The model outputs will be used to conduct spatial hotspot analyses and scenario-based simulations, providing a scientific basis for future intersection design, surveillance strategies, and spatial risk management.

E. Method of Research

      This study aims to explore the causes of near-miss events based on their frequency and involvement level. Based on the previous chapter's literature review, we collected event data and applied Zero-Inflated Multivariate Generalized Poisson (ZMGP) Models to understand which variables increase the frequency and involvement level of near-miss events.

      Given that the dataset exhibits characteristics of excessive zeros, overdispersion, and multiple correlated response variables, traditional count models are inadequate for fully capturing its structure. Therefore, this research first reviews the Zero-Inflated Poisson (ZIP) model and its ability to address the issue of excess zeros, followed by an introduction to the Generalized Poisson (GP) model for handling dispersion anomalies. Subsequently, the Zero-Inflated Generalized Poisson (ZIGP) model, which integrates zero-inflation and dispersion adjustment, is discussed. The research then explores the Multivariate Generalized Poisson (MVGP) model for accommodating multivariate data structures. Finally, it introduces the Zero-Inflated Multivariate Generalized Poisson (ZMGP) model, which is the comprehensive modeling framework adopted in this study.

F.   Results of Research

1.   Identifying intersection and driver characteristics that may increase near-miss risk

To identify latent risk factors that contribute to the occurrence of near-miss events, the study employed a Zero-Inflated Generalized Poisson (ZIGP) model. The estimation results revealed several variables that were positively associated with higher event frequencies, including perpendicular and same-direction traffic, adverse weather conditions, the involvement of cars or motorcycles, and turning maneuvers. Conversely, intersections equipped with motorcycle waiting zones, located near commercial facilities, or supported by automated enforcement technologies were found to be associated with reduced event frequencies. Additionally, the co-occurrence of peak-hour traffic and complex intersection geometry was found to significantly elevate the probability of conflict, underscoring the role of spatial configuration and traffic density in near-miss generation.

2.   Evaluating the causes of near-miss escalation and proposing targeted interventions

To further explore the escalation mechanisms of near-miss events into potential collisions, the study developed a Zero-Inflated Multivariate Generalized Poisson (ZMGP) model that simultaneously accounts for three levels of driver responses: honking, braking, and emergency braking. The findings showed that high-involvement responses were more likely to be triggered by sudden intrusions from vehicles traveling in the same direction, events occurring during the train's initial movement phase, or intersections with poor sight distance. Right-turning vehicles and illegal turning behaviors also emerged as significant contributors to medium and high-involvement events. Driver-specific factors—including male gender and both extremely high and extremely low levels of driving experience—were all significantly associated with involvement across response levels, reflecting consistent differences in behavioral reactions and operational styles. Furthermore, rainy and cloudy conditions were consistently identified as significant risk factors across all response levels, emphasizing the amplifying effect of adverse weather on driver perception and braking performance.

3.   Applying integrated statistical and spatial modeling to simulate risk hotspots and assess the effectiveness of interventions.

To support spatial decision-making, this study integrated the ZMGP model with Geographic Information Systems (GIS) to visualize expected near-miss

frequencies and involvement composition across intersections. Hotspot mapping and scenario simulation techniques were employed to identify priority locations and evaluate the impact of enforcement technologies. The results demonstrated that intersections located in densely trafficked or mixed-use areas (e.g., near stations, or public institutions) exhibited higher baseline risks but also showed substantial improvement following the installation of automated enforcement and speed cameras. These findings underscore the value of combining statistical modeling with spatial analysis in assessing risk reduction outcomes and guiding infrastructure adjustments.

G.   Future Areas to Take Note of, and Going Forward

This study has completed the development of the Multivariate Generalized Poisson (MGPO) model and the Zero-Inflated Multivariate Generalized Poisson (ZMGPO) model to simultaneously analyze multi-level near-miss outcomes and their interdependencies, providing a comprehensive depiction of event involvement and driver behavioral patterns.

In terms of spatial variables, it is recommended to incorporate additional geometric features—such as visibility distance, track curvature, and pedestrian crossing design—to enhance the explanatory power of spatial risk models.

H.   Means of Official Announcement of Research Results

Proposed as a master's thesis for the Graduate Program of Transportation and Communication Management Science, Department of Transportation and Communication Management Science, and Institute of Telecommunications Management, National Cheng Kung University (NCKU).