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Influence of Pavement Conditions on Commercial Motor Vehicle Crashes

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Introduction

Road safety is a critical concern in the United States, with Commercial Motor Vehicles (CMVs) playing a significant role in the transportation industry. This report addresses road safety concerns, focusing on Commercial Motor Vehicle (CMV) crashes in the United States, particularly in the District of Columbia's (DC) CMV routes. CMVs constitute 15% of DC's traffic, with trucks and buses accounting for 5% and 10%, respectively. In 2020, truck and bus accidents comprised 8% of reported crashes in DC. The condition of road pavements, assessed through the measurement of International Roughness Index (IRI) and Pavement Condition Index (PCI), emerges as a critical factor influencing CMV accidents. This study employs statistical and machine learning models to analyze data from the District Department of Transportation for DC CMV routes from 2016–2020. The study included collecting and analyzing relevant data, identifying correlations between pavement conditions and CMV crashes, developing predictive models, and providing insights for policymakers to enhance road safety.

Study Methods

The study examined traffic crash data obtained from the Traffic Accident Reporting and Analysis Systems Version 2.0 (TARAS2) database and pavement condition data maintained by the District Department of Transportation (DDOT) in the District of Columbia. CMV crash data was specifically collected for crashes occurring on designated CMV routes between the years 2016 to 2020. Recent measurements of International Roughness Index (IRI) and Pavement Condition Index (PCI) data for the years 2016, 2017, 2019, and 2021 were acquired from the DDOT to correlate the crash data with the pavement's condition. The research team used QGIS, a robust open-source geographic information system, to effectively manage data integration and analysis. Key dataset characteristics were examined through descriptive statistics, including mean, median, and frequency of variables. The spatial distribution and density of crashes were analyzed utilizing the ArcGIS Pro software program. Binary logistic regression was employed to explore the relationship between binary dependent variables (injury occurrence after a CMV crash) and multiple independent variables, signifying the strength and direction of correlations between predictor variables and the probability of injury. The researchers also proceeded to develop Artificial Neural Network models for classifying CMV crash injury severity based on different variables. The evaluation metrics were computed based on the Confusion Matrix. The model's architecture, including the number of hidden layers and neurons, was iteratively adjusted for optimal performance. This process continued until the best-performing model was achieved, considering parameters such as learning rate, neuron/layer count, and data quality/quantity.

Findings

The analysis revealed a significant decline of approximately 40% in the total CMV collisions on DC CMV routes in 2020 compared to 2019. However, the documented injury count to collision ratio in 2020 was higher than that of 2019. Most of the collisions resulted in property damage only, accounting for 80% of cases.

The occurrence of CMV crashes varied significantly depending on the type of roadway. Only a small fraction (4.08%) of the collisions took place on interstates, with the majority happening on non-interstate roads. The inclusion of road pavement condition variables, namely International Roughness Index (IRI) and Pavement Condition Index (PCI), significantly improved the binary logistic regression model's accuracy. These variables explained a substantial portion of the variability in CMV crash injury severity prediction. Including these variables in the model increased the predictability from 0.8% to 41%.

Additionally, Artificial Neural Network (ANN), specifically the Confusion Matrix, was also used. The best-performing model had four hidden layers with varying neuron counts, resulting in an accuracy of 60% and an F-measure of 0.52. These results highlight the potential of machine learning techniques in providing valuable insights into the complex relationship between road pavement conditions and CMV crash occurrences.

The inclusion of IRI and PCI variables in the logistic regression models increases prediction accuracy by a considerable margin, highlighting the notable relationship between road pavement conditions and CMV crash severity. Furthermore, the ANN models predicted the severity of CMV crashes with an accuracy of up to 60%.

Policy/Practice Recommendations

The findings and models developed in this research can be used by policymakers in the transportation community to prioritize and improve the road pavement conditions of CMV routes to reduce the severity of CMV crashes when they occur. By fostering quality and safer road infrastructure, the collective losses due to CMV crashes can be reduced.

About the Authors

Dr. Arhin is Professor and Chair of the Department of Civil and Environmental Engineering of Howard University, Director of the Howard University Transportation Research and Traffic Safety Data Center (HUTRC) and Research and Education in Promoting Safety (REPS), and Associate Director of this transit research project, conducted under the Mineta Consortium for Transportation Mobility.

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To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2343

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