The following implementation memo is supplemental to *NCHRP Research Report 1103: The Effect of Vehicle on Crash Frequency and Crash Severity* (NCHRP Project 22-49). The full report is available at https://doi.org/10.17226/27454.

NCHRP Project 22-49

The Effect of Vehicle Mix on Crash Frequency and Crash Severity

Technical Memorandum

Implementation of Research Findings and Products

Prepared for NCHRP
Transportation Research Board
of
The National Academies of Sciences, Engineering, and Medicine

Report Prepared by

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Background

The first edition of the Highway Safety Manual (HSM) has provided methods and procedures in estimating total crashes, crashes by type, and crashes by severity at the site level, project level and corridor level. The development of HSM in 2010 provided a compendium of practically deployable quantitative safety methods for adoption by practitioners at various agencies including states, counties, and metropolitan planning organizations. Broadly, the quantitative model components can be classified as safety performance functions (SPFs), severity distribution functions (SDFs), SPF adjustment factors (AFs), and crash modification factors (CMFs). These four model components currently do not accommodate the influence of vehicle mix, a factor shown to be valuable for explaining both crash frequency and severity. Recent research efforts have shown that heavy vehicle traffic and vehicle mix have a substantial impact on crash frequency and severity. These studies indicate that the consideration of vehicle mix would improve predictive methods for crash frequency and severity. Improved methods will result in better use of the limited funds and resources available for improving the safety of the highway system and supporting performance-based approaches. To examine how vehicle mix data can influence the model infrastructure in HSM, the NCHRP Project 22-49. titled "The Effect of Vehicle Mix on Crash Frequency and Crash Severity, NCHRP 22-49," is designed to:

- *develop and validate a statistically valid predictive methodology to quantify the effect of vehicle mix on crash frequency and severity for various facility types, and*
- *develop a spreadsheet tool for practitioners to quantify the effect of vehicle mix on safety performance across the range of highway activities including planning, design, operations, and safety management.*

Project Tasks and Outcomes

Towards accomplishing the objectives, the research team proposed two alternative approaches to incorporate vehicle mix effect in crash frequency and severity analysis: (a) negative binomial-ordered probit fractional split (NB-OPFS) method to predict crash frequency by severity levels, and (b) multivariate Poisson-lognormal (MVPLN) model to develop separate frequency models by crash severity level. The existing HSM methods serve as a benchmark for the proposed alternative approaches. The newer alternative approaches proposed have the advantage of being developed for recently completed NCHRP research (NCHRP Project 17-85) and would naturally lend themselves to modifying the HSM model structure for future versions.

This project collected crash and facility level data for 7 states (4 HSIS states including California, Illinois, Minnesota, and Washington, and 3 non-HSIS states including Connecticut, Florida, and Texas). Within each state, the research team considered the facilities that are covered in the first edition of the HSM including rural two-lane two-way roadways, rural multilane highways, urban/suburban arterials, freeway segments, and intersections. The research also focused on the total and heavy vehicle crashes during facility selection. Each facility is further categorized into multiple categories based on its attributes such as number of lanes and presence of a median (for segments), and presence of traffic control devices (for intersections). Finally, the team identified 17 segments and 7 intersections as facilities (24 in total) for developing crash prediction models.

The resulted facilities are Urban limited access segment facilities (4-lane divided, 6 lane-divided, 8-lane divided and 10-lane divided), Rural limited access segment facilities (4-lane divided, 6 lane-divided, and 8-lane divided), Urban arterial segment facilities (2-lane undivided, 3-lane, 4-lane undivided, 4-lane divided, and 5-lane), Rural arterial segment facilities (2-lane undivided, 3-lane, 4-lane undivided, 4-lane divided, and 5-lane), Urban intersection facilities (3-leg STOP controlled, 4-leg STOP controlled, 3-leg signalized, and 4-leg signalized), and Rural intersection facilities (3-leg STOP controlled, 4-leg STOP controlled, and 4-leg signalized).

The model estimation process considered a comprehensive set of independent variables including roadway characteristics (such as speed limit, lane width, median width, shoulder width, shoulder type, presence of light), traffic characteristics (aggregate level AADT), and newly compiled vehicle mix information (such as truck traffic percentage, single-unit truck traffic percentage). In terms of vehicle mix information, the team explored the availability of the vehicle mix data for each state in the project. For states with vehicle mix data available, the team used the corresponding vehicle mix variable for model estimation. On the other hand, if vehicle mix data was not available, the research team adopted the Quasi-induced exposure (QIE) technique for generating the vehicle mix data across each facility type within the state and then used the generated vehicle mix data in crash frequency and severity models for the corresponding facility. Finally, the project considered a suite of predictive performance measures to select the best model for each facility. The overall tasks of this project were unique and challenging for several reasons:

- This study made substantial efforts for collecting vehicle mix data from the states where the data are available and generated data for the states where data are not available. It was the first attempt at creating crash prediction models for states incorporating vehicle mix information.
- Estimating separate models for all the facilities for each state will require a substantial amount of time and effort. Therefore, for each facility type, a single dataset was prepared by pooling records from all the available states for that facility type. This data pooling technique will assist safety researchers and modeling practitioners to develop models efficiently.
- The research team and panel recognized that offering different model options for different facility types might result in confusion and incorrect adoption among users. Hence, the single model that predominantly performed better within a facility group was selected for that facility group. The single model for a facility group will assist state agencies to be consistent in crash estimation across the U.S.
- The project developed user-friendly Excel spreadsheet tools and made the tools, supporting input data and user guidance available to be used by a wide variety of agencies—including state DOTs, regional MPOs, and other transportation safety agencies.

The research team made every effort to make the prediction models and developed tools effective for practical implementation. This memorandum describes the work that could expedite the process to move the research outputs toward implementation in practice.

Suggestions for Implementation

The crash frequency and severity prediction models incorporating vehicle mix information developed in this research provide a new set of capabilities and tools that have not previously been incorporated into the crash prediction practice. However, as practitioners have experience with HSM crash prediction model implementation, the newly developed models and tools that follow the same structure would be readily deployable in practice. The research team recognizes that effective dissemination of the research results will assist in better implementation. Hence, the project team prepared a detailed PowerPoint-style presentation that is suitable to present at both AASHTO Committee on Safety and the TRB Highway Safety Committee meetings. The presentation document includes speaker notes, background, objectives, research approach, findings, conclusions, and a demonstration of the spreadsheet tools developed in this project. In addition, a summary of the research findings was prepared for publication in TRB's widely circulated Transportation Research News. Together, these efforts were designed to promote initial awareness of the research findings and the modeling tools that have been developed.

The final report of the project describes the data compilation techniques, vehicle mix data generation techniques, modeling approaches, model performance measures and comparison techniques, and model result presentation techniques. This report will allow the professionals, researchers and safety modeling practitioners to understand the techniques well enough to implement them in existing or new crash prediction model systems. In addition, the software codes implementing the model and the process for using the codes provided will also assist the safety analysts and transportation modeling practitioners to use them in crash analysis. Furthermore, the project effort also produced a guidebook for using the new models and tools. This guidance document is designed to aid the practitioners in implementing the models.

In addition to TRB's Cooperative research Programs, there are several organizations including federal (U.S. DOTs), state (state DOTs), and regional agencies (MPOs) as well as academic institutions that teach crash prediction models could support efforts to implement the models developed in this research.