Using Event Data Recorders to Compare the Frontal Cash Injury Prediction Capabilities of Six Vehicle-Based Crash Severity Metrics

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Introduction

The Manual for Assessing Safety Hardware outlines the crash test procedures for roadside barriers, such as guardrails [1]. Since 1981, these tests have assessed occupant risk using two vehicle-based crash severity metrics: occupant impact velocity (OIV) and ridedown acceleration (RA). Due to significant advances in roadside and passive safety, there is a need to assess whether these metrics still reliably predict occupant injuries in real-world crashes. The objective of this study was to compare the frontal crash injury prediction capabilities of six vehicle-based crash severity metrics: maximum delta-v (MDV), OIV, RA, occupant load criterion (OLC), acceleration severity index (ASI), and vehicle pulse index (VPI).

Approach

This study used in-depth, real-world crash data from the Crash Investigation Sampling System (CISS) from years 2017 to 2019 [2]. CISS is a probability sample of all US crashes in which at least one passenger vehicle was towed from the scene, and records occupant injury using the 2015 Abbreviated Injury Scale (AIS). The AIS is a medically-relevant injury scale that categorizes injuries into six severity levels, AIS1 to AIS6, where 6 is an unsurvivable, or fatal, injury. A subset of the crashes recorded in CISS can be paired with the Virginia Tech event data recorder (EDR) database. EDRs provide a more comprehensive overview of the crash, as they record pre-crash and crash characteristics, such as the travel speed and delta-v crash pulse.

Passenger vehicle drivers in frontal, single-event crashes were selected for analysis. The longitudinal delta-v crash pulse must have been available from the vehicle's EDR, as it was necessary to compute all six metrics. Occupant injury data was used to determine the maximum AIS value (MAIS) for each occupant. Six initial binary logistic regression models were constructed to predict the risk of an MAIS2 or greater injury, including a fatal injury (MAIS2+F). The models were developed using one of the metrics and six binary covariates: belt status, sex, age, obesity, vehicle body type, and principal direction of force. Final models were constructed using the statistically significant ($p < 0.05$) covariates. The F2 scores from the training data were used to compare the models' predictive capabilities (Eq. 1).

$$F^2 = \frac{(5)(Precision)(Recall)}{(4 * Precision) + (Recall)} \quad \text{(Eq. 1)}$$

Results

The models were trained using 184 sampled occupants, representing 80,030 real-world occupants. The metric and belt status were significant in every final model. Sex was significant in the ASI and VPI models. When significant, being belted and being female lowered the risk of an MAIS2+F injury (Table 1). Based on the F2 scores, the OLC model is most equipped to accurately predict occupant MAIS2+F injury risk in frontal crashes.

Table 1. Parameter coefficients, p-values, and F2 scores six final models. Reference values for each covariate are noted below the covariate name.

Model	Metric		Belt Status		Sex		F2 Score
	--		Unbelted		Female		
	Coeff.	P-Value	Coeff.	P-Value	Coeff.	P-Value	
MDV	0.55	< 0.001*	-2.40	0.007*	--	--	0.73
OIV	0.72	0.001*	-2.85	0.009*	--	--	0.73
RA	0.68	0.001*	-1.61	0.026*	--	--	0.66
OLC	0.31	0.001*	-3.05	0.012*	--	--	076
ASI	4.94	0.001*	-2.79	0.004*	1.89	0.024*	0.69
VPI	0.02	0.001*	-2.65	0.005*	1.98	0.020*	0.67

Conclusions

The OLC model had the highest F2 score, however there was little difference among the predictive capabilities of the metrics. Future work will assess the models' predictive capabilities on a new test dataset. This is the first study to develop frontal crash injury risk models using the CISS and EDR databases.