EXPLORING MICROSCOPIC CRASH MECHANISMS OF FREEWAY-TO-FREEWAY INTERCHANGE RAMPS

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1. AIM

Freeway-to-freeway interchange ramps are critical components of freeway networks. The safety of interchange ramps is a major concern. In order to provide high speed traffic transfer between two separating freeways, interchange ramps are designed to have horizontal or vertical curvatures or both. These curvatures make interchange ramps much more complicated and dangerous than freeway mainline segments. Previous research has indicated that the crash rates of interchange ramps were much high than mainlines. Thus, the safety of interchange ramps needs to be explored.

2. METHOD

In order to better understand the crash mechanisms of interchange ramps, this work builds bayesian multilevel Poisson-lognormal models to estimate 3-hour interval crash frequencies, and bayesian multilevel logistic regression models to predict real-time crash risks. Comparing to the safety studies based on Annual Average Daily Traffic (AADT), the 3-hour interval crash frequency and real-time crash risk studies are more microscopic and can better capture the traffic condition at the time of crashes. As for the multilevel modeling structure, it was used to capture the unobserved heterogeneities among events, which happened on the same segment. All models are applied to both single-vehicle (SV) and multi-vehicle (MV) crashes, because the crash mechanisms for the SV and MV are different according to previous studies.

In addition, in the real-time safety analysis, this study explored the feasibility of using crash reports to identify roadway surface conditions (RS) at study sites, which is an important crash-contributing factor. Previously, in order to obtain the RS information, weather information from weather stations is used if roadways are close to weather stations. However, some roadways are far away from the stations (more than five miles), hence, the weather stations might not be able to provide accurate RS information. When this situation happens, crash reports served as a supplement of the weather station to provide more accurate RS information for roadway events. Figure 1 illustrates the process of obtaining RS.

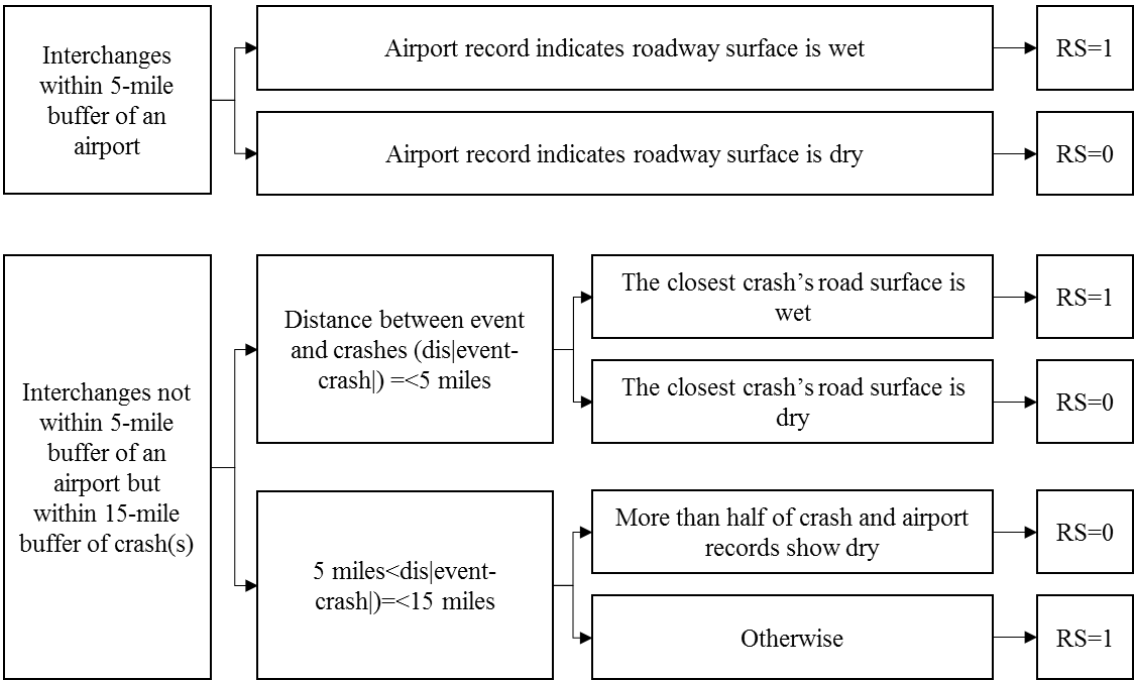

Figure 1: Data Preparation for Roadway Surface Condition (RS=1 means wet roadway surface)

3. RESULTS

The crash frequency models revealed that the logarithm of 3-hour traffic volume and average turning angle were positive significant parameters in estimating SV crash frequency; and high traffic volume, sag, or downgrade vertical curve increased MV crash frequency. Meanwhile, the real-time models revealed that the average turning angle had a positive impact on SV crash risk. MV crash risk increases if lane occupancy increases or interchange ramp vertical alignment is a downgrade. Additionally, comparing the SV to the MV model, it was found that volume has more impact on MV crashes. Furthermore, the real-time crash estimation models also indicated that RS was one of the most important parameters: wet roadway surfaces increase SV crash ratio by 8.87 and MV crash ratio by 2.82. The parameter estimation for the 3-hour crash frequency model is shown in Tables 1 and 2.

Table 1: Parameter Estimation for Crash Frequency Models

Variable	Mean	Std.	95% CI
Single-vehicle Crash			
Intercept	-2.16	0.31	(-2.81, -1.56)
Log(3-hour interval volume)	0.25	0.11	(0.04, 0.45)
Average Turning Angle	3.31	1.31	(0.82, 6.02)
DIC			568.75
Multi-vehicle Crash			
Intercept	-2.26	0.28	(-2.83, -1.74)
Log(3-hour interval Volume)	1.07	0.15	(0.79, 1.40)
Sag	0.92	0.36	(0.27, 1.67)
Downgrade	0.99	0.36	(0.29, 1.66)
DIC			542.43

Table 2: Parameter Estimation for Real-time Crash Risk Estimation Model

Variable	Mean	Std.	95% CI	Odds ratio
Single-vehicle Crash Risk Model				
Intercept	-3.71	0.49	(-4.76, -2.87)	0.02
Road Surface (RS)	2.29	0.31	(1.69, 2.93)	9.87
Average Turning Angle	3.14	1.82	(-0.28, 7.10)*	23.10
DIC			371.34	
Calibration ROC			0.88	
Validation ROC			0.86	
Multi-vehicle Crash Risk Model				
Intercept	-4.16	0.43	(-5.03, -3.36)	0.02
Occupancy	0.14	0.02	(0.10, 0.18)	1.15
RS	1.34	0.33	(0.72, 2.00)	3.82
Daytime	0.78	0.36	(0.08, 1.52)	2.18
Downgrade	0.71	0.41	(-0.14, 1.47)*	2.03
DIC			356.96	
Calibration ROC			0.90	
Validation ROC			0.86	

* Significant at the 90% confidence interval

This study proved that implementing crash reports was an effective method of providing a study event's weather information. After adding the weather information from crash reports, 36.8% more studied events get roadway surface condition information, and the accuracy also increases by 7.4%.

4. CONCLUSION

Freeway-to-freeway interchange ramps are critical components of freeway networks. The safety of interchange ramps is a concern because of their complicated horizontal and vertical alignment. While there is no safety study of interchange ramps from microscopic aspects, which are crash frequency based on 3-hour intervals and real-time crash risk. In order to better understand the crash mechanism of interchange ramps, this work builds multilevel Poisson-lognormal models to estimate crash frequencies in 3-hour intervals and multilevel logistic regression models to predict real-time crash risks. All models are applied to both SV and MV crashes. At the same time, this study explores the feasibility of using crash reports to provide pavement conditions for study events.

The finding of this study about the impact of horizontal curve and vertical alignment on crash frequency can be added to the HSM. The Highway Safety Manual (HSM) states that the effects of the interchange ramp roadway's vertical alignment is still unknown, and the magnitude of a horizontal curve on crashes is not certain. Moreover, since the roadway surface condition has been proven to be significant in real-time crash risk, practitioners could consider countermeasures, such as applying high friction pavement at interchanges.