“Analysis of Factors Affecting the Frequency of Crashes on Interstate Freeways by Vehicle Type and Severity Incorporating Weather Prediction Models”

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Introduction

- Focus of study funded by the Arizona Board of Regents (ABOR) Research Innovation Fund (RIF) – Collaborative effort between NAU, UA, and ASU.
- Year 1 of the ABOR RIF project focused primarily on the I-10 as a high freight corridor
- **Year 2 focus was beyond the I-10, and is meant to include the Arizona megaregion including interstates connecting Flagstaff, Phoenix, Tucson, and Yuma.**
- Other funding for this project came from the Pacific Southwest Region 9 UTC
Objective

Primary Goals

- When considering the entire interstate system in AZ, what roadway variables, factors contribute significantly to the frequency of crashes?
- Do these roadway variables affect the frequency of crashes of different vehicle types in a similar manner?
- Do these roadway variables affect the frequency of crashes of different severity levels in a similar manner?
- Does incorporating validated weather prediction data provide statistically significant results?
Background – Data Sources

- AZ Crash Reports statewide
  - 2010 to 2016
  - Incidents
- Geometric data package provided by ADOT’s Multimodal Planning Division (MPD)
- Datasets to analyze frequency of crashes
- Looked at Interstates 8, 10, 17, 19 and 40.
Crash Frequency Models

- Negative Binomial Model with Random Effects
- NB is a generalized form of Poisson model:

  \[ N_p = EXP(\beta_0 + \beta_1 X_1 + \ldots \beta_i X_i) \]

  Where:
  \( N_p \): predicted number of annual crashes
  \( \beta \): vector of estimable parameters
  \( X_i \): vector of explanatory (independent) variables

  * Random effects allows the intercept term, \( \beta_0 \), to vary across observations in order to account for unobserved geographic and temporal effects.
The Arizona meteorological Network (AZMET) operates 40 weather stations with 29 active and 11 inactive stations all around Arizona.

Data was validated based on observation data from AZMET by generating annual precipitation data and plotting against the available stations.
Weather Research and Forecasting Models

- Observed Precipitation (P) from AZMET versus the simulated precipitation (P) obtained from WRF.
- $r^2 = 0.87$ shows a strong agreement between the simulated and the observed data.
# Frequency Model Descriptive Statistics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>Std.Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment Length</td>
<td>3.40</td>
<td>3.06</td>
<td>0.19</td>
<td>21.38</td>
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<tr>
<td>Directional AADT</td>
<td>58.778</td>
<td>64.566</td>
<td>1.324</td>
<td>307.709</td>
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<td>Ln(Directional AADT)</td>
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<td>1.01</td>
<td>7.19</td>
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<td>Annual Total Precipitation (inches)</td>
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<td>5.26</td>
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<td>Concrete Barrier</td>
<td>0.28</td>
<td>0.45</td>
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<td>1.00</td>
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<tr>
<td>Cable Barrier</td>
<td>0.16</td>
<td>0.36</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>No Barrier</td>
<td>0.67</td>
<td>0.47</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Median Width &lt;39 Feet</td>
<td>0.26</td>
<td>0.44</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Median Width 40-79 Feet</td>
<td>0.59</td>
<td>0.49</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Median Width &gt;80 feet</td>
<td>0.15</td>
<td>0.35</td>
<td>0.00</td>
<td>1.00</td>
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<tr>
<td>Right Shoulder (Feet)</td>
<td>10.08</td>
<td>1.48</td>
<td>6.00</td>
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<tr>
<td>Left Shoulder (Feet)</td>
<td>5.57</td>
<td>2.92</td>
<td>3.00</td>
<td>16.00</td>
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<tr>
<td>2 Lanes</td>
<td>0.67</td>
<td>0.47</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>3 or 4 Lanes</td>
<td>0.25</td>
<td>0.43</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>5 or 6 Lanes</td>
<td>0.10</td>
<td>0.29</td>
<td>0.00</td>
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<tr>
<td>HOV Lane</td>
<td>0.19</td>
<td>0.39</td>
<td>0.00</td>
<td>1.00</td>
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<tr>
<td>Speed Limit &lt;65 mph</td>
<td>0.12</td>
<td>0.33</td>
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<tr>
<td>Speed Limit 65-75 mph</td>
<td>0.21</td>
<td>0.41</td>
<td>0.00</td>
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<tr>
<td>Speed Limit 75 mph</td>
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<td>0.00</td>
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<tr>
<td>Degree of Curvature</td>
<td>0.12</td>
<td>0.54</td>
<td>0.00</td>
<td>4.47</td>
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<tr>
<td>Percent Grade</td>
<td>1.15</td>
<td>1.04</td>
<td>0.00</td>
<td>6.35</td>
</tr>
<tr>
<td>Truck Percent</td>
<td>18.88</td>
<td>13.06</td>
<td>2.24</td>
<td>94.00</td>
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<tr>
<td>Phoenix</td>
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<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Tucson</td>
<td>0.10</td>
<td>0.30</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Yuma</td>
<td>0.01</td>
<td>0.12</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Flagstaff</td>
<td>0.03</td>
<td>0.16</td>
<td>0.00</td>
<td>1.00</td>
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<tr>
<td>All Crashes</td>
<td>16.76</td>
<td>24.57</td>
<td>0.00</td>
<td>320.00</td>
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<tr>
<td>No Injury (O)</td>
<td>11.90</td>
<td>17.69</td>
<td>0.00</td>
<td>229.00</td>
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<td>Possible Injury (C)</td>
<td>2.10</td>
<td>4.07</td>
<td>0.00</td>
<td>54.00</td>
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<tr>
<td>Non-Incapacitating Injury (B)</td>
<td>2.21</td>
<td>3.27</td>
<td>0.00</td>
<td>39.00</td>
</tr>
<tr>
<td>Incapacitating Injury (A)</td>
<td>0.40</td>
<td>0.77</td>
<td>0.00</td>
<td>6.00</td>
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<tr>
<td>Fatal (K)</td>
<td>0.16</td>
<td>0.44</td>
<td>0.00</td>
<td>5.00</td>
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<tr>
<td>No Injury/Possible Injury (O+C)</td>
<td>14.00</td>
<td>21.42</td>
<td>0.00</td>
<td>283.00</td>
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<tr>
<td>Non-Incapacitating/Incapacitating/Fatal (B+A+K)</td>
<td>2.77</td>
<td>3.69</td>
<td>0.00</td>
<td>44.00</td>
</tr>
</tbody>
</table>

1 Binary Indicator Variable (0 or 1)
2 Annual Crashes Per Segment
Total Crash Numbers

- Total Crashes 78,675
  - Passenger Vehicle: 65,203
  - Freight Vehicle: 11,675
  - Motorcycle: 1,355
  - Bus/RV/Trailer: 442

- Total Crashes 78,675
  - Injury Severity K: 763
  - Injury Severity A: 1,888
  - Injury Severity B: 10,351
  - Injury Severity C: 9,856
  - Injury Severity O: 55,817
## Results Table Output

<table>
<thead>
<tr>
<th>Freight Vehicle Model</th>
<th>( \beta )</th>
<th>Std. Error</th>
<th>P-Value</th>
<th>Std. Dev</th>
<th>Std. Error</th>
<th>P-Value</th>
</tr>
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<tbody>
<tr>
<td>Intercept</td>
<td>-5.717</td>
<td>0.264</td>
<td>&lt;0.001</td>
<td>0.204</td>
<td>0.014</td>
<td>&lt;0.001</td>
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<td>Segment Length</td>
<td>0.087</td>
<td>0.006</td>
<td>&lt;0.001</td>
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<td></td>
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<tr>
<td>Ln(AADT)*</td>
<td>0.564</td>
<td>0.021</td>
<td>&lt;0.001</td>
<td>0.007</td>
<td>0.001</td>
<td>&lt;0.001</td>
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<td>Precipitation (inches)</td>
<td>0.027</td>
<td>0.003</td>
<td>&lt;0.001</td>
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<tr>
<td>Concrete Barrier</td>
<td>-0.518</td>
<td>0.071</td>
<td>&lt;0.001</td>
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<tr>
<td>No Barrier*</td>
<td>-0.439</td>
<td>0.081</td>
<td>&lt;0.001</td>
<td>0.183</td>
<td>0.017</td>
<td>&lt;0.001</td>
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<tr>
<td>Median Width 40-79 Feet</td>
<td>-0.100</td>
<td>0.047</td>
<td>0.034</td>
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<td>Median Width &gt;80 feet</td>
<td>0.057</td>
<td>0.059</td>
<td>0.340</td>
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<tr>
<td>Right Shoulder (Feet)*</td>
<td>0.008</td>
<td>0.011</td>
<td>0.496</td>
<td>0.010</td>
<td>0.001</td>
<td>&lt;0.001</td>
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<tr>
<td>Left Shoulder (Feet)</td>
<td>0.013</td>
<td>0.008</td>
<td>0.108</td>
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<td>2 Lanes</td>
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<td>0.088</td>
<td>&lt;0.001</td>
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<td>3 or 4 Lanes</td>
<td>-0.237</td>
<td>0.072</td>
<td>0.001</td>
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<tr>
<td>HOV Lane</td>
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<tr>
<td>Speed Limit 75 mph</td>
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<td>0.061</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Degree of Curvature*</td>
<td>0.037</td>
<td>0.027</td>
<td>0.165</td>
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<td>0.023</td>
<td>0.017</td>
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<tr>
<td>Percent Grade*</td>
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<td>0.780</td>
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<tr>
<td>Truck Percent</td>
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<td>0.002</td>
<td>&lt;0.001</td>
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<tr>
<td>Phoenix</td>
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<td>0.070</td>
<td>&lt;0.001</td>
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<td>Tucson</td>
<td>-0.239</td>
<td>0.074</td>
<td>&lt;0.001</td>
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<td>Yuma</td>
<td>-0.377</td>
<td>0.185</td>
<td>0.041</td>
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<tr>
<td>Flagstaff</td>
<td>0.045</td>
<td>0.104</td>
<td>0.661</td>
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<tr>
<td>Over-Dispersion**</td>
<td>0.376</td>
<td>0.132</td>
<td>&lt;0.001</td>
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<td></td>
</tr>
</tbody>
</table>

* Random Parameter in Model
** Over-dispersion parameter for the negative binomial model framework.
Passenger Vehicle Model Results

Total Crashes: 65,203

Beta Values for Explanatory Variables (Passenger)

- Segment Length
- Ln(AADT)
- Precipitation (inches)
- Concrete Barrier
- No Barrier
- Median Width 0-40 feet
- Median Width > 40 feet
- Right Shoulder (Feet)
- Left Shoulder (Feet)
- 2 Lanes
- 3 or 4 Lanes
- HOV Lane
- Speed Limit 65-75 mph
- Speed Limit > 75 mph
- Degree of Curvature
- Percent Grade
- Truck Percent
- Phoenix
- Tucson
- Yuma
- Flagstaff

Statistically Significant
Freight Vehicle Model Results

Total Crashes: 11,675

Beta Values for Explanatory Variables (Freight)
Motorcycle Model Results

Total Crashes: 1,355

Beta Values for Explanatory Variables (Motorcycle)

- Statistically Significant
Bus/RV/Trailer Model Results

Total Crashes: 442
Beta Values for Explanatory Variables (Bus/RV/Trailer)

- Statistically Significant
Injury Severity Levels C/PDO
Model Results

Total Crashes: 65,673

Beta Values for Explanatory Variables (C/PDO)
Injury Severity Levels K/A/B Model Results

Total Crashes: 13,002

Beta Values for Explanatory Variables (K/A/B)

- Segmented Length
- Ln(AADT)
- Precipitation (Inches)
- Concrete Barrier
- Median Width < 176 Feet
- Median Width > 176 Feet
- Right Shoulder (Feet)*
- Left Shoulder (Feet)*
- 2 Lanes
- 3 or 4 Lanes
- HOV Lane
- Speed Limit 65-75 mph
- Speed Limit 75+ mph
- Degree of Curvature*
- Percent Grade*
- Truck Percent
- Phoenix
- Tucson
- Yuma
- Flagstaff

Statistically Significant
Percent Increase in Predicted Crash Frequency
Conclusions

- One of the primary contributions of this paper was using WRF model to obtain accurate, validated precipitation data.
- Precipitation Variable was statistically significant in all models except the Bus/RV/Trailer and Motorcycle models.
  - In all cases it was statistically significant it was a positive Beta value indicating an increase in the frequency of crashes
- The HOV lane increases the frequency of both frequency-severity models in this paper.
  - This was seen in the passenger vehicle, motorcycle, and severity models.
  - Other lane numbers were not significant in all models (except 2 lanes for passenger vehicles and C/PDO crashes)
- Agencies should focus on educational campaigns on how to drive in severe weather conditions (not just rain) and HOV usage.
- Agencies should focus on employing new ITS technologies to increase driver awareness and performance.
ITS Countermeasures: Connected Vehicles

- Adaptive Cruise Control
- Collision avoidance technology
- Lane Departure Alerts
- WRF could potentially be used as a source for weather predictions for an in-vehicle sensor for vehicle to vehicle communication
ITS Countermeasure: Active Traffic Management

- Benefits of ATM mainly for congestion caused by crashes.
  - Smoother traffic flow
  - Reduces bottleneck by informing the driver where to merge safely.
  - Can help reduce secondary crashes
  - Can change speed limits for hazardous weather and crashes
  - Shown to decrease crash frequency by 29% in a study in Seattle
ITS Countermeasure: Dynamic Speed Limits

- Cheaper alternative to ATM
- Can change speed limits based on current road and weather conditions. (rain, dust, snow)
Thank You.
Questions?

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