# Examination of Factors Associated with Fault Status and Injury Severity in Intersection-Related Rear-End Crashes

RSS Paper #149

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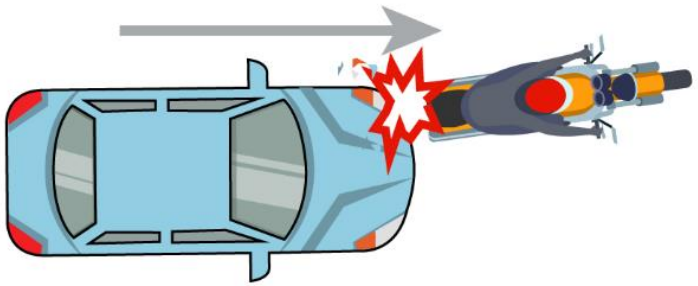
# Motivation: Rear-End Crashes

- Most common collision type among police-reported crashes in the United States (US), representing 32.5% of all reported crashes.
- There were 2,346 fatal rear-end crashes and 595,000 injury rear-end crashes (representing 31.1% of all injury crashes) in the US in 2019 alone.
- Occur when one vehicle fails to slow or stop and impacts the rear of the lead vehicle.
- Can occur due to variety of reasons (speed, inattentiveness, impairment, weather conditions, etc.), and generally the driver of the following vehicle is deemed to be ‘at-fault’ for causing the crash.



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# Literature Review Summary

Rear-End Crash Severity Analyses:

- Yu et al. (2020) and Zhang & Hassan (2019) investigated severity of rear-end crashes in work zones.
- Chen et al. (2015) and Chen et al. (2019) investigated severity of all rear-end crashes in New Mexico and across the US, respectively.
- Common findings related to increased severity of rear-end crashes include:
  - Truck involvement
  - Dark lighting conditions
  - Male driver involvement
  - Drug/alcohol involvement
  - Higher speeds
- Chen et al. (2019) used bivariate framework and concluded there was significant correlation between the injury severity of drivers involved in the same crash.

# Objectives and Contribution

- Previous research has focused on rear-end crash severity specifically in work zones or across an entire network.
  - None have focused on intersection-related rear-end crashes
  - characteristics may vary given the variation in speeds and behavior related to interaction with traffic control and possible queuing at intersections
- Previous work has not investigated factors associated drivers being ‘at-fault’ and causing the rear-end crash to occur

Primary Objective:

- Analyze factors associated with fault status and injury severity (and the interrelation between the two) in two-vehicle intersection-related rear-end crashes.

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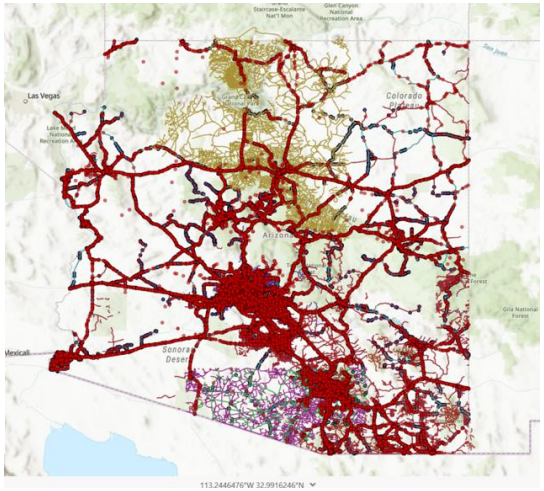
# Data Description

- US State of Arizona Crash Data (2014-2018)
- ‘Rear-End’ collision type flagged as intersection-related excluding:
  - Any crash involving any number of units other than two.
  - Any crash involving a bicyclist or pedestrian.
  - Any crash where the injury severity for either of the two drivers was unknown.
  - Any crash in which both drivers or neither driver were identified as ‘at-fault’.
- Fault status determined by identifying which driver was issued a violation in the crash:
  - “followed too closely”
  - “speed too fast for conditions”
  - “inattention/distraction”



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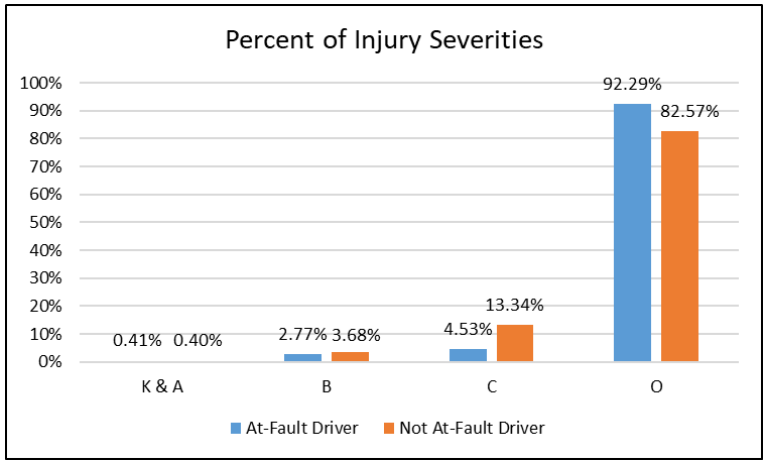
# Data Description

- Final data set included 62,006 crashes (124,012 drivers).
- Severity measured using 'KABCO' scale:
  - K = fatal injury
  - A = Serious/incapacitating injury
  - B = Minor/non-incapacitating injury
  - C = Possible Injury
  - O = No injury (property damage only)

Intersection types:
- Four Way Intersection
- T-Intersection
- Y-Intersection
- Intersection as Part of Interchange
- Traffic Circle
- Roundabout
- Five Point or More

| Injury Severity of Not-At-Fault Drivers | Injury Severity of At-Fault Drivers | | | | Total |
|---|---|---|---|---|---|
| | No Injury (O) | Possible Injury (C) | Minor Injury (B) | Serious or Fatal Injury (A&K) | |
| **No Injury (O)** | 48,395 | 1,575 | 1,050 | 181 | **51,201 (82.57%)** |
| **Possible Injury (C)** | 6,912 | 1,078 | 247 | 36 | **8,273 (13.34%)** |
| **Minor Injury (B)** | 1,733 | 140 | 396 | 13 | **2,282 (3.68%)** |
| **Serious or Fatal Injury (A&K)** | 188 | 14 | 23 | 25 | **250 (0.40%)** |
| **Total** | **57,228 (92.29%)** | **2,807 (4.53%)** | **1,716 (2.77%)** | **255 (0.41%)** | **62,006 (100.0%)** |

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# Summary Statistics

- Crash-specific variables

| Crash Variable | Number | Percent |
|---|---|---|
| County | | |
| Maricopa | 47,169 | 76.07% |
| Pima | 5,652 | 9.12% |
| Others | 9,185 | 14.81% |
| Total | 62,006 | 100% |
| Crash Day | | |
| Weekend (Saturday-Sunday) | 44,660 | 72.03% |
| Weekday (Monday-Friday) | 17,346 | 27.97% |
| Total | 62,006 | 100% |
| Type of Intersection | | |
| Four Way Intersection | 44,569 | 71.88% |
| T-Intersection | 12,457 | 20.09% |
| Y-Intersection | 1,418 | 2.29% |
| Intersection as Part of Interchange | 2,747 | 4.43% |
| Traffic Circle | 57 | 0.09% |
| Roundabout | 223 | 0.36% |
| Five Point or More | 535 | 0.86% |
| Total | 62,006 | 100% |
| Light Condition | | |
| Daylight | 50,283 | 81.09% |
| Dark | 9,397 | 15.15% |
| Dawn & Dusk | 2,326 | 3.75% |
| Total | 62,006 | 100% |

| Crash Variable | Number | Percent |
|---|---|---|
| Road Alignment | | |
| Straight | 53,917 | 86.95% |
| Curve Left | 539 | 0.87% |
| Curve Right | 2,551 | 4.11% |
| Unknown | 4,999 | 8.06% |
| Total | 62,006 | 100% |
| Lane | | |
| Left Turn Lane | 5,450 | 8.79% |
| Right Turn Lane | 5,776 | 9.32% |
| Others | 45,507 | 73.39% |
| Unknown | 5,273 | 8.50% |
| Total | 62,006 | 100% |
| Speed of vehicle | | |
| Speed 25 mph and Below | 3,508 | 5.66% |
| Speed 30-50 mph | 51,310 | 82.75% |
| Speed 55 mph and Above | 5,248 | 8.46% |
| Unknown | 1,940 | 3.13% |
| Total | 62,006 | 100% |
| Surface Condition of Road | | |
| Surface Dry | 59,376 | 95.87% |
| Surface Wet | 2,300 | 3.71% |
| Surface Snow & Ice | 154 | 0.25% |
| Other (sand, mud, etc…) | 75 | 0.12% |
| Unknown | 101 | 0.16% |
| Total | 62,006 | 100% |

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# Summary Statistics

- Person- and Vehicle-specific variables

| Driver Variable | At-Fault Driver | | Not-At-Fault Driver | | All Drivers | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Driver Gender | | | | | | |
| Male | 34,823 | 56.16% | 31,011 | 50.01% | 65,834 | 53.09% |
| Female | 26,277 | 42.38% | 30,926 | 49.88% | 57,203 | 46.13% |
| Unknown | 906 | 1.46% | 69 | 0.11% | 975 | 0.79% |
| Total | 62,006 | 100% | 62,006 | 100% | 124,012 | 100% |
| Driver Seatbelt Use | | | | | | |
| Driver Belted | 56,383 | 90.93% | 58,907 | 95.00% | 115,290 | 92.97% |
| Driver Unbelted | 2,174 | 3.51% | 1,533 | 2.47% | 3,707 | 2.99% |
| Safety Device Use Unknown | 3,449 | 5.56% | 1,566 | 2.53% | 5,015 | 4.04% |
| Total | 62,006 | 100% | 62,006 | 100% | 124,012 | 100% |
| Driver Alcohol and Drug Use | | | | | | |
| Driver Did Not Use Alcohol or Drugs | 59,658 | 96.21% | 61,962 | 99.93% | 121,620 | 98.07% |
| Driver Used Alcohol or Drugs | 2,348 | 3.79% | 44 | 0.07% | 2,392 | 1.93% |
| Total | 62,006 | 100% | 62,006 | 100% | 124,012 | 100% |
| Driver Age | | | | | | |
| Age 24 and Below | 18,716 | 30.18% | 8,988 | 14.50% | 27,704 | 22.34% |
| Age 25-63 | 36,585 | 59.00% | 45,683 | 73.68% | 82,268 | 66.34% |
| Age 64 and Above | 5,749 | 9.27% | 7,221 | 11.65% | 12,970 | 10.46% |
| Unknown | 956 | 1.54% | 114 | 0.18% | 1,070 | 0.86% |
| Total | 62,006 | 100% | 62,006 | 100% | 124,012 | 100% |
| Vehicle Use | | | | | | |
| Car | 45,345 | 73.13% | 47,194 | 76.11% | 92,539 | 74.62% |
| Van | 2,090 | 3.37% | 2,077 | 3.35% | 4,167 | 3.36% |
| Pickup | 10,642 | 17.16% | 9,314 | 15.02% | 19,956 | 16.09% |
| Truck | 1,461 | 2.36% | 1,200 | 1.94% | 2,661 | 2.15% |
| Bus | 123 | 0.20% | 315 | 0.51% | 438 | 0.35% |
| Recreational Vehicle (RV) | 22 | 0.04% | 12 | 0.02% | 34 | 0.03% |
| Motorcycle | 486 | 0.78% | 429 | 0.69% | 915 | 0.74% |
| Unknown | 1,837 | 2.96% | 1,465 | 2.36% | 3,302 | 2.66% |
| Total | 62,006 | 100% | 62,006 | 100% | 124,012 | 100% |
| Distracted | | | | | | |
| Driver Distracted | 19,003 | 30.65% | 2,321 | 3.74% | 21,324 | 17.20% |
| Driver Did Not Distracted | 43,003 | 69.35% | 59,685 | 96.26% | 102,688 | 82.80% |
| Total | 62,006 | 100% | 62,006 | 100% | 124,012 | 100% |
| Rollover | | | | | | |
| Rollover Occurred | 55 | 0.09% | 52 | 0.08% | 107 | 0.09% |
| Did Not Rollover | 61,951 | 99.91% | 61,954 | 99.92% | 123,905 | 99.91% |
| Total | 62,006 | 100% | 62,006 | 100% | 124,012 | 100% |

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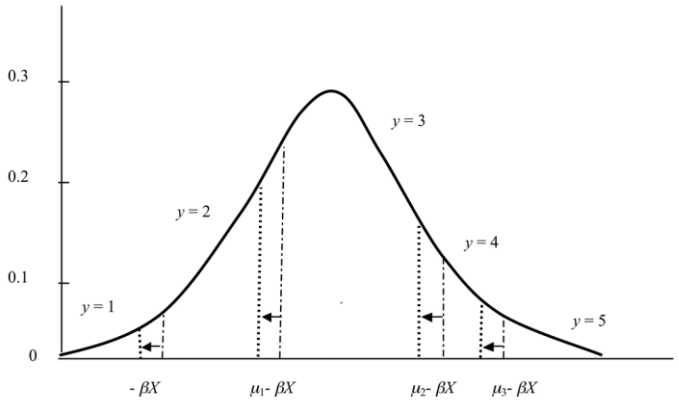
# Statistical Methodology

- Investigating factors associated with fault status:
  - Binary dependent variable (1='at-fault', 0='not at-fault')
  - Binary probit model developed
  - After model estimation, positive parameter estimate indicates increased probability of being at-fault, and vice versa for negative parameter estimates.
- Investigating factors associated with driver injury severity:
  - Ordered dependent variable (O, C, B, A&K)
  - Possible within-crash correlation of injury severities
  - Bivariate ordered probit model developed
    - Injury severity of both crash-involved drivers modeled jointly
  - After model estimation, positive parameter indicates increased probability of K or A injury, and vice versa for negative parameter estimates.




Source: Washington, S., Karlaftis, M., and F. Mannering. Statistical and Econometric Methods for Transportation Data Analysis (2nd ed.)

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# Results: Fault Status

- Factors Associated with Fault Status using Binary Probit Model

| Variable | Coefficient | Std. Error | P-value |
|---|---|---|---|
| Constant | -0.1516 | 0.0725 | 0.0365 |
| Car | 0.4133 | 0.0679 | <0.0001 |
| Van | 0.5060 | 0.0709 | <0.0001 |
| Pickup | 0.5190 | 0.0684 | <0.0001 |
| Truck | 0.6243 | 0.0725 | <0.0001 |
| Recreational Vehicle (RV) | 0.9832 | 0.2533 | 0.0001 |
| Motorcycle | 0.3720 | 0.0849 | <0.0001 |

'Bus' excluded as reference

# Results: Injury Severity

- Results of the Bivariate Ordered Probit Injury Severity Model

| Variable | At-Fault Driver | | | Not-At-Fault Driver | | |
|---|---|---|---|---|---|---|
| | Coefficient | Std. Error | P-value | Coefficient | Std. Error | P-value |
| Constant | -1.1711 | 0.0748 | <0.0001 | -1.1532 | 0.0569 | <0.0001 |
| Weekend | -0.0375 | 0.0195 | 0.0545 | -0.0497 | 0.0148 | 0.0008 |
| Daylight | -0.0660 | 0.0216 | 0.0023 | - | - | - |
| Maricopa County | -0.1349 | 0.0195 | <0.0001 | -0.1004 | 0.0154 | <0.0001 |
| T-Intersection | 0.1649 | 0.0208 | <0.0001 | 0.0483 | 0.0162 | 0.0029 |
| Roundabout | - | - | - | -0.3981 | 0.1292 | 0.0021 |
| Interchange Intersection | 0.1371 | 0.0435 | 0.0016 | - | - | - |
| Straight Road Alignment | 0.1226 | 0.0468 | 0.0088 | - | - | - |
| Left Turn Lane | -0.1743 | 0.0311 | <0.0001 | -0.0823 | 0.0231 | 0.0004 |
| Right Turn Lane | -0.4367 | 0.0397 | <0.0001 | -0.1225 | 0.0232 | <0.0001 |
| Speed 30-50mph | 0.3170 | 0.0432 | <0.0001 | 0.1820 | 0.0304 | <0.0001 |
| Speed 55+ mph | 0.3320 | 0.0522 | <0.0001 | 0.2698 | 0.0362 | <0.0001 |
| Surface Ice | -0.9009 | 0.4752 | 0.0580 | -0.3405 | 0.1507 | 0.0238 |
| Van (Driver) | -0.2179 | 0.0519 | <0.0001 | - | - | - |
| Pickup (Driver) | -0.2956 | 0.0270 | <0.0001 | -0.0719 | 0.0192 | 0.0002 |
| Truck (Driver) | -0.5378 | 0.0804 | <0.0001 | -0.3852 | 0.0584 | <0.0001 |
| Bus (Driver) | -0.6454 | 0.3830 | 0.0919 | -0.6270 | 0.1196 | <0.0001 |
| Motorcycle (Driver) | 1.1280 | 0.0710 | <0.0001 | 1.0073 | 0.0775 | <0.0001 |
| Van (Other vehicle) | 0.1689 | 0.0439 | 0.0001 | 0.0719 | 0.0356 | 0.0437 |
| Pickup (Other vehicle) | 0.1982 | 0.0223 | <0.0001 | 0.0753 | 0.0169 | <0.0001 |
| Truck (Other vehicle) | 0.4812 | 0.0507 | <0.0001 | - | - | - |
| Bus (Other vehicle) | 0.5344 | 0.0918 | <0.0001 | 0.2875 | 0.1355 | 0.0339 |
| Motorcycle (Other vehicle) | -0.2226 | 0.1230 | 0.0704 | -0.8229 | 0.1119 | <0.0001 |
| Rollover | 1.2862 | 0.1422 | <0.0001 | 1.4337 | 0.1621 | <0.0001 |
| Distracted | 0.0856 | 0.0180 | <0.0001 | 0.0768 | 0.0338 | 0.0231 |
| Age 25-63 | 0.0803 | 0.0193 | <0.0001 | 0.2173 | 0.0196 | <0.0001 |
| Age 64 and Above | 0.2740 | 0.0291 | <0.0001 | 0.2435 | 0.0257 | <0.0001 |
| Female | 0.2156 | 0.0176 | <0.0001 | 0.2129 | 0.0135 | <0.0001 |
| Belted | -0.8122 | 0.0354 | <0.0001 | -0.1911 | 0.0448 | <0.0001 |
| Alcohol & Drugs | 0.3334 | 0.0386 | <0.0001 | - | - | - |
| Threshold 1 | 0.4686 | 0.0099 | <0.0001 | 0.8033 | 0.0096 | <0.0001 |
| Threshold 2 | 1.4227 | 0.0286 | <0.0001 | 1.7530 | 0.0248 | <0.0001 |
| Correlation (ρ) | 0.4314 | 0.00961 | <0.0001 | | | |
| Restricted Log Likelihood | -42,123.29 | | | | | |
| Log Likelihood @ Convergence | -41,313.29 | | | | | |

Significant correlation coefficient

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# Conclusions and Implications

- Enforcement- or education-related activities aimed at preventing intersection rear-end crashes should focus on:
  - drivers of RVs and trucks
  - young (age 24 or less) and male drivers
  - driver distraction and impairment
- To reduce severity outcomes of this crash type, focus should be placed on:
  - T-intersections and interchange-related intersections
  - rural areas with poor lighting and/or high speed limits
  - driver distraction and impairment
- Potential countermeasures include:
  - improved lighting
  - warning signs (particularly at unsignalized intersections)
  - high-friction pavement treatments
  - speed reduction
  - improved signal visibility and/or clearance interval timing at signalized intersections

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# Limitations and Future Work

- Data for this study were obtained only from the US state of Arizona
  - The results are likely transferable to similar areas, but may not represent all geographic regions as weather conditions, driver behavior, and other factors may vary.
- Study focused only on driver injury severity
  - Passenger injury could be investigated (including rear-seat passengers)
- Actual speed data for crash-involved vehicles were not available for this study
  - Additional insights on the impact of speed (particularly speed of at-fault vehicles) on injury severity could be obtained with these data.

# Thank You

## Comments/Questions?

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