TRAFFIC SAFETY ALONG TOURIST ROUTES IN RURAL AREAS

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Little is known about the safety of tourist drivers in the United States. Most domestic studies on tourist driver safety have focused on traffic deaths/injuries of U.S. citizens traveling abroad, citing chief factors such as left-side driving, low rate of seat belt use, and alcohol consumption. For states with a number of tourism attractions, and roadways to reach them, it is of interest to investigate whether traffic safety is an issue for tourist drivers. To that end, this research work investigated the contributing factors for crash severity and crash likelihood of park-visiting drivers in or near three national parks in rural areas. Driver-level data from Rocky Mountain National Park and Sequoia and Kings Canyon National Park revealed risk factors for crash severity including age, geometry, and seat-belt usage, among others. To anticipate crash likelihood for visiting drivers, a second data set from Yellowstone National Park offered a more microscopic view at the road level. It contained road geometry, traffic volume, environment, and crash counts aggregated at the segment level along a 57.8-mile tourist route of U.S. Highway 89 (a primary route to Yellowstone’s north entrance). Crash risk factors (e.g., geometry and traffic intensity) affected local and non-local (tourist) drivers in different ways. Further exploration of crash trends in specific parks would be valuable to understand the overall trends and contributors to crashes in tourism areas and determine effective improvement measures.

**Key Words:** tourist drivers, traffic safety, crash severity, crash frequency, ordered probit model, spatial multivariate count model, national parks
INTRODUCTION

While much progress has occurred in the area of traffic safety, little attention has been paid to the safety of tourist drivers in the United States. Most domestic studies on tourist driver safety have focused on traffic deaths/injuries of U.S. citizens traveling abroad, citing chief factors such as driving on the opposite side of the road, low rates of seat belt use, alcohol consumption, vehicle condition, driver fatigue, roadway and pavement conditions, and lighting (1). Within the United States, the dearth of national or local statistics on crashes involving tourist drivers is behind the sparse research and results. For states with a number of tourism attractions, and roadways to reach them, it is in the interest of public health to investigate whether traffic safety is an issue for tourist drivers. Understanding tourist traffic safety is important to the economy, too. In Montana for example, tourism brought in $3.98 billion in revenue and supported 55,270 jobs in 2013 (2). These tax and job benefits are likely to be offset by the economic and societal costs of traffic crashes involving tourists. While estimated crash costs vary due to a myriad of factors like severity levels, congestion impacts, and collision manners, traffic crashes in general impose large economic and societal costs (e.g., the economic cost of a road fatality in the United States averages $5.83 million, including lifetime productivity loss, lawsuits, emergency medical service costs, etc.) (3).

To better understand tourist driver safety in the United States, this research study investigated the contributing factors for crash severity and crash likelihood of park-visiting drivers in or near three national parks. While an exploratory study, the research sheds light on the relevant risk factors and the relationship between visitor drivers and local drivers in traffic crashes. The results can be useful in offering policy considerations for places where visitors/tourists regularly use personal automobiles as a means of transportation.

This paper begins with a Literature Review, followed by a Data Sets section about the data processing details. The descriptive analysis and statistical modeling used are explained next in the Methodology section. Modeling results and interpretation are presented in the Results and Analysis section. Policy and planning implications are found in the Discussion and Recommendation sections, while limitations and future research are discussed in the Conclusions section.

LITERATURE REVIEW

Domestic research on tourist traffic safety has been sparse except for a few epidemiologic reports on traffic safety of U.S. citizens traveling overseas (1). A number of international studies have focused on traffic safety in tourism areas. Rosselló and Saenz-de-Miera (4) examined the role of tourism in the number of daily crashes in the Balearic Islands of Spain. The researchers noted that there existed a void when trying to assess the non-economic impacts of tourism (externalities), specifically aspects such as traffic crashes. The approach considered traditional variables used in safety prediction (e.g., traffic volumes and weather) as well as a daily measure for the number of tourists at a destination. This measure consisted of observations and...
estimations of arrivals and departures on the islands via airports and seaports (cruise ships). A negative binomial model was developed to estimate crashes, with the model parameters estimated using the quasi-maximum likelihood method. Using the model, different simulations were run to determine the impact of tourism on crashes. The results indicated that, all other factors being equal, the presence of tourism accounted for 15.8 percent more crashes on the islands than if tourism was not present.

Page and Meyer performed an exploratory analysis of tourism accidents in New Zealand (5). The researchers focused on more than just vehicle crashes in their work, examining insurance/medical claims from highway crashes, sports/recreation injuries, home/lodging injuries and “other” (unspecified) types of accidents. In a review of Accident Rehabilitation and Compensation Insurance Scheme (ACC) data for the year ending June 30, 1994 (the ACC provides a no-fault system of coverage for both New Zealanders and visitors injured as a result of an accident), the researchers found 6,742 insurance claims per 1,000 visitors to New Zealand. Of these, roadway crashes resulted in 3,063 claims per 1,000 visitors. Land Transport Safety Authority data was also examined as part of the work to better understand trends of crashes involving foreign drivers. It was observed that 1.1 percent of all crashes in New Zealand in 1993 involved international drivers. Of the 52 crashes involving foreign drivers, only 16 were determined by police to be caused by the drivers themselves. Based on observations made from the data examined, the researchers concluded that while foreign drivers were not a major factor in the country’s overall observed crashes, they do represent a problem in terms of rental car crashes. To this end, potential strategies to address tourist crashes for rental cars included showing videos on common precautions to take, screening of safety messages at car rental agencies, pamphlets and leaflets, prominent signage near airports, tourist resorts, and rental car agencies reminding drivers that New Zealanders drive on the left-hand side of the road, and signs on interior vehicle panels to remind drivers of road rules.

Petridou et al. (6) examined the epidemiology of crashes on the island of Crete. Data from a six-month period from April to September 1995, involving 730 injury victims from traffic crashes who were admitted to three hospitals in the Heraklion District, were examined to determine the patterns, causes, and effects of those crashes. Calculation of odds ratios and statistical documentation was done using the Mantel–Haenszel procedure, which the researchers noted generated results equivalent to those derived from multiple logistic regression. The evaluation found that left-side driving country nationals were at an increased risk for traffic crashes when they drove a rented vehicle ($p = 0.02$), and were involved 2.5 times more frequently in crashes in which passing or other driving maneuvers required reflexes conditioned on reverse directionality ($p=0.02$) (6). Alcohol was a primary cause of crashes in a significantly higher proportion of foreign nationals ($p < 10^{-6}$) and was more common among Eastern Europeans than those from European Union countries ($p < 10^{-5}$) (6). The authors concluded that based on these findings, crashes represent a major hazard during pleasure travel and that the victims of those crashes have a distinct epidemiologic profile compared to local residents.
Another research study (7) sought to determine whether crash injuries were disproportionately higher among tourists on the island of Kerkyra (Corfu) in Greece. The researchers examined data from the Emergency Department Injury Surveillance System for all types of accidents, including traffic crashes for 1996 and 1997. Injury comparisons were made between injuries from vehicle crashes versus home and leisure-related injuries. Proportions and chi-square tests were used for the statistical analysis of the data. Examination of the data indicated that traffic crashes represented 40 percent of all injury accidents among foreign tourists. Among foreign tourists, the peak tourism to non-peak tourism ratio for injury accidents was 9.2 for non-traffic accidents, but 15.0 for traffic crashes. The difference between these ratios was statistically significant (P = 0.008), and it appeared that crashes among foreign tourists were disproportionately frequent.

Leviäkangas (8) examined the crash risk of foreign drivers (primarily Russian) in southeast Finland. Specifically, the research focused on differences in crash rates between Russian (foreign) and Finnish (domestic) drivers on two-lane main roads. The results indicated that the crash rates of foreign drivers were much higher than the corresponding rates of Finnish drivers. For example, the crash rate for foreign drivers on one route was 157.7 per 100 million vehicle kilometers versus the Finnish driver rate of 47.6. Winter was observed to be an especially risky season for foreign drivers.

**DATA SETS**

Two separate data sets are used in this study to examine the safety issues (i.e., crash likelihood and severity levels) along tourist routes. Both crash data sets report a very small fraction (less than 0.5 percent) of international drivers involved in crashes, but a significant number of domestic non-local drivers (those whose driver’s license is issued by a state other than the home state of the park or the corridor).

The first data set combines crash records from Rocky Mountain National Park (ROMO) in Colorado with records from Sequoia and Kings Canyon National Park (SEKI) in California. The data set contains information on 1,467 crash drivers involved in 1,184 crashes from 2006 to 2012, along with crash severity levels, road geometry, pavement conditions, and environmental factors (e.g., lighting conditions). Along with one fatal crash (which occurred in ROMO in 2007), the data showed there were 24 incapacitating injuries, 74 non-incapacitating injuries, and 43 possible injuries. The remaining 90.3 percent of crash drivers sustained no injury. Given the unbalanced nature of the crash severity, the five severity levels from the data set were grouped into two categories—injury crashes (fatal, incapacitating injury, and non-incapacitating injury) and non-injury crashes (possible and no injury). The two-level variable (y = 1 if injury, 0 if no injury) was used as the response variable.

Explanatory variables are defined by a vector of continuous and indicator variables, including driver characteristics (e.g., age, gender, if local driver, and use of seat belt); speed limits; surface conditions (0 = Dry; 1 = Icy/Slushy/Snowy or Debris/Muddy/Wet); lighting (0 = Daylight; 1 = Dawn/Dusk; 2 = Dark); and road geometry (Straight and Level; Straight on Grade; Curved and
Level; Curved on Grade). The ROMO-SEKI data also provided vehicle makes and models for the drivers. These data were streamlined into three vehicle types—compact, medium-sized (Size.Med.), and full-sized (Size.Larg.) vehicles. Summary statistics are shown in Table 1.

**TABLE 1 Summary Statistics of the ROMO-SEKI Crash Data (No. of Observations = 1,092)**

<table>
<thead>
<tr>
<th>Covariates</th>
<th>Average</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>If Male (0 = Female; 1 = Male)</td>
<td>0.783</td>
<td>1</td>
<td>0.412</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Use Restraint (1 = Yes; 0 = No)</td>
<td>0.877</td>
<td>1</td>
<td>0.328</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Lighting (0=Daylight; 1=Dawn/Dusk; 2=Dark)</td>
<td>0.287</td>
<td>0</td>
<td>0.797</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Surface (0=Dry; 1=Otherwise)</td>
<td>0.291</td>
<td>0</td>
<td>0.455</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>If non-local</td>
<td>0.454</td>
<td>0</td>
<td>0.498</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>If Straight on Grade</td>
<td>0.212</td>
<td>0</td>
<td>0.409</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>If Curved &amp; Level</td>
<td>0.111</td>
<td>0</td>
<td>0.314</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>If Curved on Grade</td>
<td>0.326</td>
<td>0</td>
<td>0.469</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>If Medium Size</td>
<td>0.294</td>
<td>0</td>
<td>0.456</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>If Full Size</td>
<td>0.619</td>
<td>1</td>
<td>0.486</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>If Compact Size</td>
<td>0.087</td>
<td>0</td>
<td>0.282</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Age</td>
<td>44.60</td>
<td>45</td>
<td>15.86</td>
<td>14</td>
<td>88</td>
</tr>
<tr>
<td>Speed Limit (mile per hour)</td>
<td>23.72</td>
<td>25</td>
<td>12.00</td>
<td>0</td>
<td>75</td>
</tr>
<tr>
<td><strong>Response Variable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If injured/killed (1 = Yes; 0 = No)</td>
<td>0.061</td>
<td>0</td>
<td>0.240</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

To anticipate crash likelihood of visiting drivers, the second data set offers a more microscopic view at the road level. It contains road geometry, traffic volume, environment, and crash counts aggregated at the segment level along a tourist route of U.S. Highway 89. This route stretches 57.8 miles from Livingston to Gardiner, Montana, and serves as the primary route to the north entrance of Yellowstone National Park. Traffic volume or average daily traffic (ADT) was obtained from a dozen temporary and permanent count stations through the Montana Department of Transportation (MDT). Three years of original crash data were obtained from the Montana Department of Justice. Unlike a typical crash form, the original data are stored at the driver or unit level, along with personal information such as driver license state, age, and gender. From 2011 to 2013, inclusive, a total of 163 vehicle crashes were reported along the corridor and involved a total of 214 drivers.
Road geometry attributes were collected from the Road Log Database from MDT. The video logs capture road alignments, surrounding environment, and the pavement underneath from cameras mounted on a survey vehicle. After post-processing, the database converts some of the video information to numeric values, including the vertical grade in percent and the Light Weight Profiler (LWP) International Roughness Index (IRI) at every 1/10th second interval. The road video was used by the research staff to define homogenous road segments, resulting in a total of 105 segments with uniform horizontal alignment. Each segment was further defined by rural/urban environment and cross-section (i.e., number of lanes). Given the absence of land parcel maps, which are useful for calculating built environment variables, the built environment is described by a rural/urban indicator and by the number of signalized and stop-controlled intersections and access points (i.e., driveways or other small access roads that lead to land use on both sides of the roads). Roadside clear zone was recorded in three levels—poor, fair, and good—depending on the presence of sight obstructions near traffic lanes such as trees, poles, and other built structures.

In order to anticipate the underlying crash rates for local and non-local drivers, their representations in traffic were also collected. Field data collection took place at three intersections for a total of six hours on a weekday in July of 2015. The purpose was to gauge the percentage of local versus non-local vehicles. A 15-minute interval was used to aggregate vehicle counts grouped into local (Montana-licensed) vehicles and non-local vehicles. The three count stations were selected from three towns along the route—Livingston, Emigrant, and Gardiner—to reflect the changes in the ratios between local and non-local vehicles as the road approaches the park. The Livingston station (the farthest station from the park) produced a local vehicle percentage of 73 percent, Emigrant showed 51 percent local vehicles, and Gardiner (the closest station to the park) 34 percent. Table 2 provides summary statistics for the U.S. 89 data set.

**TABLE 2** Summary Statistics of the U.S. 89 Data Set (No. of Observations = 105 segments)

<table>
<thead>
<tr>
<th>Covariates</th>
<th>Average</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment Length (miles)</td>
<td>0.551</td>
<td>0.309</td>
<td>0.719</td>
<td>0.031</td>
<td>5.611</td>
</tr>
<tr>
<td>Percent of Local Traffic</td>
<td>0.491</td>
<td>0.511</td>
<td>0.164</td>
<td>0.344</td>
<td>0.733</td>
</tr>
<tr>
<td>If Horizontal Curve (1 = Yes; 0 = No)</td>
<td>0.524</td>
<td>1.000</td>
<td>0.502</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>LWP IRI</td>
<td>82.03</td>
<td>70.35</td>
<td>54.24</td>
<td>37.27</td>
<td>523.20</td>
</tr>
<tr>
<td>No. of Access Points</td>
<td>3.057</td>
<td>1.000</td>
<td>5.354</td>
<td>0.000</td>
<td>30.000</td>
</tr>
<tr>
<td>No. of Signalized Intersections</td>
<td>0.038</td>
<td>0.000</td>
<td>0.237</td>
<td>0.000</td>
<td>2.000</td>
</tr>
<tr>
<td>No. of Stop-Controlled Intersections</td>
<td>0.452</td>
<td>0.000</td>
<td>1.594</td>
<td>0.000</td>
<td>12.000</td>
</tr>
<tr>
<td>Roadside Clear Zone (0 = poor; 1 = Fair; 2 = Good)</td>
<td>1.505</td>
<td>2.000</td>
<td>0.722</td>
<td>0.000</td>
<td>2.000</td>
</tr>
<tr>
<td>If Urban (1 = Yes; 1 = No)</td>
<td>0.105</td>
<td>0.000</td>
<td>0.308</td>
<td>0.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>
METHODOLOGY

This research focused on safety issues surrounding domestic park-visiting drivers. Since traffic within ROMO and SEKI is predominantly park visitors, the modeling results can be extrapolated to tourist drivers—both local visitors and non-local visitors. While a major route for park visitors, the U.S. 89 corridor studied also serves local, non-tourism traffic. Therefore, an assumption was made regarding the definition of tourists and hence a limitation of this study: non-local (out-of-state) drivers are considered to represent visitors (mostly park visitors), as opposed to local drivers (some of whom may be park visitors too, but their percentage is unknown). Nevertheless, the interactions between local and non-local drivers relative to traffic crash occurrence, as investigated here, are useful for understanding whether the mix has safety implications.

The research mainly answered two questions: what factors contribute to crash rates and severity levels of park visitors; and is there a difference in crash likelihood and severity levels between park visitors/drivers and local drivers? These questions were answered by statistical analyses of traffic crash records from within the two national parks (driver-level data) and from the tourism corridor along U.S. Highway 89 (segment-level data).

An ordered probit model (OP) was used to estimate the crash severity levels using the ROMO-SEKI data set. The mathematical form is shown in Equation 1:

\[ y = \begin{cases} 
0 & \text{if } y^* \leq 0 \\
1 & \text{if } y^* > 0 
\end{cases} \text{ and } y^* = x^\prime \beta + \epsilon \]  

where \( y \) is the observed crash outcome (\( y = 1 \) if fatal or injured; \( y = 0 \) otherwise); \( y^* \) measures the latent risk of fatal/injurious crashes and is expressed as a function of the covariates, or \( x \)'s (e.g., road, environment, and driver characteristics), their coefficients (\( \beta \)'s), and the error term (\( \epsilon \)) that follows a normal distribution. The OP model is a typical tool for analyzing ordered responses; see, for example, Ratanavaraha and Suangka’s study on crash severity levels and their respective crash loss values (9), and Lemp et al.’s extension to account for heteroscedasticity for large-truck crash severity levels (10).

A spatial count model was used to simultaneously estimate crash rates of local and non-local drivers while controlling for geometry, environment, and driver attributes. The spatial model was used to mitigate issues associated with missing variables (e.g., lighting, sight distance, and pavement conditions) that show spatial dependence. More mathematical details are referred to in these studies: (11), (12), and (13). The model consists of two stages. The first stage is expressed by a standard Poisson model:
\[ y_{ik} \sim \text{Poisson}(\lambda_{ik}) \]  

where \( y_{ik} \) is the number of drivers that crashed at segment \( i \); \( k \) denotes the type of drivers (\( k = 1 \) if local drivers; \( k = 2 \) if non-local drivers). The mean crash counts, \( \lambda_{ik} \), is coded in the second stage as:

\[ \lambda_{ik} = E_{ik} \cdot \exp(x_i^T\beta_k + \phi_{ik} + u_i) \]  

where \( E_{ik} \), the exposure term, is defined as a product of segment length and traffic volume (ADT); the unknown parameter \( \alpha \) captures any non-linear relationship between exposure and the mean crash counts of segment \( i \). The vector \( x_i \) is shorthand for the covariates (e.g., traffic volume, a curve indicator, roadside clear-zone conditions, number of access points and intersections, and a constant term); \( \beta_k \) is a vector of the coefficients specific to driver type \( k \). \( \phi_{ik} \) represents a random effect term defined by a multivariate conditional autoregressive distribution (13) to reveal spatial dependence within each driver type and the correlation between the two types of drivers. The remaining unexplained variation is described by the heterogeneity error term, \( u_i \), unique for each segment.

**RESULTS AND ANALYSIS**

The OP model revealed factors that contribute to fatal/injury crashes in ROMO and SEKI, as summarized in Table 3. Eliminating data with missing variables, the model was run over a total of 1,092 crash drivers.

Older tourist drivers were more likely to be injured in a crash than younger drivers, and the use of safety restraints (e.g., seatbelt) can help prevent injuries, as statistically confirmed by the results. Road geometry was coded into four indicator variables: Straight and Level (set as the reference level or Road.0), Straight on Grade (Road.1), Curved and Level (Road.2), and Curved on Grade (Road.3). Results show that complex geometry involving either vertical or horizontal curves or both contributed to the likelihood of injury crashes.

Higher speed limit correlated with higher severity level, a finding echoed in research on the relationship between speed and severity (14, 15). Vehicle size is a standard factor for crash outcomes, as full-sized vehicles offer more protection to the occupants than smaller vehicles (16). Results suggest that larger vehicle size correlated with lower injury levels (of the occupants), with more reduction benefits from full-sized vehicles than medium-sized vehicles. However, it is possible that large vehicles imposed more devastating impacts and hence increased the severity level of drivers of the other vehicles. But this presumption was not tested by this study due to data constraints.

Among the environmental factors, dark lighting conditions (Light.Dark) were found to be a moderate predictor for fatal/injury crashes, significant under a 90 percent confidence level (\( z \) value = 1.83). Roadway surface was cast in a binary way—Surface = 0 if dry and 1 representing all the remaining, compromised surface conditions, such as snowy, icy, slushy, wet, with debris,
or muddy. Results suggest that adverse surface conditions contributed to lower severity levels, which is consistent with previous findings; see, e.g., (17). Intuitively, drivers tend to slow down under bad weather or surface conditions, and lower speed often prevents serious crash injuries.

The initial model also tested whether non-local visitors/drivers were more likely to be injured in crashes than local drivers. The rationale was that non-local drivers are not as familiar with the roads as local drivers and more prone to errors (perhaps grave ones) due to wayfinding and operating rental vehicles. Based on the OP results, severity levels did not seem to vary between local and non-local tourist drivers, as reflected by a weak significance level, and hence were removed from the final model.

**TABLE 3 Outputs of the Ordered Probit Model for Severity Levels**

|          | Coef.  | Std. Err. | z     | P>|z|   | 95% Conf. Interval |
|----------|--------|-----------|-------|-------|-------------------|
| Age      | 0.010  | 0.004     | 2.2   | 0.028 | 0.001 - 0.018     |
| Restraint| -0.585 | 0.177     | -3.32 | 0.001 | -0.931 - 0.239    |
| Light.Dark| 0.379  | 0.207     | 1.83  | 0.067 | -0.027 - 0.785    |
| Surface  | -0.351 | 0.165     | -2.13 | 0.034 | -0.675 - 0.027    |
| Size.Med | -0.542 | 0.199     | -2.73 | 0.006 | -0.932 - 0.153    |
| Size.Large| -0.758 | 0.188     | -4.02 | 0.000 | -1.127 - 0.389    |
| Speed.Limit | 0.022 | 0.006     | 3.54  | 0.000 | 0.010 - 0.034     |
| Road.1   | 0.678  | 0.210     | 3.23  | 0.001 | 0.267 - 1.089     |
| Road.2   | 0.656  | 0.251     | 2.61  | 0.009 | 0.164 - 1.149     |
| Road.3   | 0.762  | 0.202     | 3.78  | 0.000 | 0.367 - 1.158     |
| Cutoff value (Constant) | 1.999 | 0.351 |       | 1.311 - 2.689    |

No. of Obs. = 1,092
LR chi²(1) = 82.54
Likelihood = -210.63299
Pseudo R² = 0.1638

To evaluate crash risk factors of local/non-local drivers, the study used three years of crash data from a tourist corridor of U.S. Highway 89—a primary route to Yellowstone’s north entrance. Figure 1 plots the distributions of the two types of drivers against various road and environmental factors. Curve vs. Straight: Horizontal curves represent 28.6 percent of road centerline miles of the corridor studied. While the majority of crashes occurred along straight segments, a higher percentage of non-local drivers (38 percent) were involved in crashes along horizontal curves than local drivers (23 percent). Number of access points: This variable measured the number of driveways along each homogenous road segment as a proxy for potential traffic conflicts. Local drivers appeared to be
over-represented on segments with many access points, whereas non-local drivers were over-
represented along segments with fewer access points.

Roadside clear zone: Coded into three levels (poor, fair, and good), this variable referred to the
presence of obstructions (e.g., poles and built structures) in close proximity to traffic lanes such
that it affected a driver’s ability to traverse back to the roadway. A clear divide is identified
between non-local drivers and local drivers in that the former were more likely to crash in
impaired clear zones.

Rural/Urban: Ninety percent of the studied corridor lies in rural areas, with a small section of the
roadway crossing town centers in Livingston, Emigrant, and Gardiner (coded as urban). A higher
percentage of local drivers were involved in crashes in those urban areas. This can be attributed
to a higher exposure of local drivers, as many are residents and patrons of local businesses.

Intersections: Segments with at least one signalized or stop-controlled intersection bore a higher
percentage of local driver crashes than non-local driver crashes. This could result from the local
drivers representing a greater share of the turning traffic (in order to access land use). As an
exploratory research, the study was not able to drill down into the causes of the disparities. This
can be achieved perhaps by looking into the behavioral and operational aspects of local/non-local
drivers at intersections in future research.

So far, the interactions between local and non-local drivers were not considered. To make that
consideration, driver license information available from the crash records during the 2011 to
2013 period were processed to determine if a crash involved only local drivers or at least one
non-local driver. To control for the different exposures for local and non-local traffic, a field
study was conducted at the three locations along the corridor to gauge the ratios between local
and non-local traffic by observing the vehicle license plates (Montana or out-of-state). For the
corridor under study, the average percentage of local (Montana) license plates was 56.5 percent.
As shown in Figure 2, local drivers represented 64 percent of the 136 single-vehicle crashes. The
pattern was reversed for multi-vehicle crashes (a total of 27 over the three years), with non-local
drivers representing 64 percent of the multi-vehicle crashes, mostly colliding with a Montana-
licensed vehicle. This distinct pattern between local and non-local drivers is perhaps attributed to
speed differences between local and non-local drivers and the tendency of non-local drivers to
engage in wayfinding, scenic viewing, and possibly different driving behaviors.
(a) Curves and Straight Segments  
(b) Number of Access Points  
(c) Clear Zone Conditions  
(d) Rural and Urban  
(e) Segments w/ +1 Signalized Intersections  
(f) Segments w/ +1 Stop-Controlled Intersections  

**FIGURE 1** Comparisons between Local and Non-Local Drivers Involved in Crashes by Roadway and Environment Features
A spatial count model was used on the crash data set of U.S. 89 to identify primary risk factors for local and non-local drivers while controlling for spatial dependence between segments as a result of missing variables. Estimated at the segment level, the model related road geometry, traffic volume, and environmental factors to the number of local and non-local drivers who were involved in traffic crashes during the 2011–2013 period. Table 4 summarizes the model results. The deviance information criterion (DIC) was used to measure the overall goodness of fit of the model. The model was run using the Bayesian Markov Chain Monte Carlo method with the statistical packages R and WinBUGS (18). A total of 15,000 samples were drawn for each unknown parameter—the first 3,000 draws were discarded as burn-ins and the remaining 12,000 samples were retained to produce the means and standard deviations for estimating the parameters.

**FIGURE 2** Distributions of Local and Non-Local Drivers in Collision Patterns and Traffic

**TABLE 4** Results of the Spatial Count Model for Bivariate Response (No. of Observations = 105)
The bivariate response refers to the counts of local and non-local drivers, analyzed simultaneously. Pseudo t-statistics measure statistical significance; larger absolute values indicate pronounced effects. After controlling for traffic exposure (i.e., the average number of local and non-local vehicles traveling along each segment), traffic volume or AADT was estimated to contribute to non-local driver crash risk but negatively correlated with local-driver crash risk in statistically significant ways. This finding suggests that local drivers cope well with higher traffic conditions as opposed to non-local drivers, whose crash risk increases with higher traffic. The number of access points correlated with higher crash rates for non-local drivers, while its effect on local drivers was insignificant. The model was not able to discern the predictive powers of some variables (e.g., radius), possibly due to the small sample size (No. of Observations = 105).

Thanks to the spatial and bivariate structure, the model also captured spatial dependence among segments and cross-correlations between the two types of drivers in crash occurrence. Local drivers tend to cluster along road segments, as do non-local drivers, as reflected by the statistically significant parameters $\rho_1$ and $\rho_2$. The non-spatial correlation parameter, $\eta_0$, measures the relationship between local and non-local driver counts of the same road segment, whereas the parameter, $\eta_1$, measures the two types of drivers’ correlation that tend to trend in space. Results suggest that road segments that experience a larger number of local-driver crashes also tend to see more non-local-driver crashes, indicating adverse safety impacts due to the interactions between local and non-local drivers. These adverse effects are estimated to spill over to adjacent segments, as revealed by the positive coefficient, $\eta_1$.

**DISCUSSION**

Based on the modeling results of the ROMO-SEKI crashes, several observations can be made. First, older drivers were more likely to be injured in crashes than their younger counterparts. Of course, this in part is related to the increased frailty associated with aging, but it also may be related to the general demographics visiting parks and other attractions. Older drivers may
comprise a larger proportion of the visitor population to such locations (higher disposable income, more leisure time, etc.) and thus have a higher exposure to crashes.

The finding that more complex geometry contributes to the likelihood of crashes in these locations further underscores the potential relationship that unfamiliar drivers to an area may have with crashes. Complex geometry, combined with the potential for inattentiveness/distraction (viewing scenery, etc.) may combine to make certain locations more dangerous to visitors than they would be in a normal driving environment.

The observation that larger vehicle sizes are tied to lower injury crashes is intuitive in the sense that a bigger vehicle provides more protection for occupants, but it may also underscore a unique aspect of tourism-related destinations and traffic composition. It is likely that tourists are driving larger vehicles to these destinations, such as recreational vehicles, pickup trucks with camper trailers, SUVs and so forth. As a result, when crashes occur, they may be more likely to involve a larger vehicle and potentially reduced injuries.

Finally, the lighting conditions, specifically darkness, being a moderate predictor of crashes is logical, as unfamiliar drivers to an area are likely to encounter more difficulties when driving on roads they have not been on before. The lower crash severity associated with snowy/wet pavements is also related closely with unfamiliar drivers who are likely to drive more slowly during inclement conditions in an area they are visiting. Additionally, parks often have seasonal visitation trends, and visits during the winter are likely to be lower and result in lower potential for severe or injurious crashes during inclement conditions.

Observations from the U.S. 89 data provide a general view of potential features that may contribute to crashes involving unfamiliar drivers in tourism areas. Curvature was observed to have higher crash involvement for non-local drivers, underscoring that unfamiliarity with a route may present unexpected challenges. Similarly, areas with clear-zone issues saw non-local drivers more frequently involved in crashes. Such locations may coincide with unique roadside scenery or other distractions, resulting in increased potential for crash occurrence. Further investigation into such crashes is required before this can be confirmed.

The spatial count model run for the U.S. 89 dataset revealed a couple of interesting findings. First, while the finding that higher traffic volumes increased the crash risk for non-local drivers was intuitive, it underscored the challenges that potentially face such drivers in what is an unfamiliar and often complex driving environment. Conversely, the observation that local driver crash risk was not impacted by higher traffic volumes indicates that this driver population has, in part, apparently learned to cope over time with the impacts of tourist traffic. Second, the finding that local and non-local drivers tend to share common crash locations points toward the potential need for roadway improvements or other measures to address crashes at specific sites or in specific ways, particularly for unfamiliar drivers.
RECOMMENDATION

Based on the findings of this work, several recommendations can be made. First, further research, particularly crash modeling, is necessary to better understand the overall trends and contributors to crashes in tourism areas, particularly sites such as national parks. The research presented here was exploratory in nature and only sought to establish whether non-local drivers were involved to a greater extent in crashes in tourism areas. It appears that non-local drivers are presented with challenges in such locations, and follow-up work should investigate particular aspects of crashes, such as roadway geometry, in greater detail.

A second recommendation is that the development and distribution of educational materials should be considered to prepare drivers for their visit to an area. To an extent, many parks already do this in terms of providing maps. Since these materials exist, it would not be difficult to add tips for driving in the area to these materials, such as being aware that there may be frequent hills, curves, etc. on local roads and to exercise caution when driving.

Finally, further exploration of crash trends in specific parks is needed to determine if improvements to signage and wayfinding are needed (e.g., curve delineation with chevrons). While signage installations must be balanced with aesthetic considerations in scenic areas, the benefits to roadway safety need to be heavily considered. Also tied to this is the need for additional research to better understand the nature of crashes in tourist locations in general to determine what additional safety treatments might be considered to address crash patterns.

CONCLUSIONS

Evidence from this exploratory analysis suggests that national parks and the corridors that lead to them present challenges to non-local drivers who are visiting the area for tourism-related reasons. Issues such as complex geometry may present challenges to unfamiliar drivers, especially older ones. Similarly, reduced lighting conditions and their relationship to crashes are illustrative of the challenges drivers face when traveling in an unfamiliar area. General observations from a corridor leading to a national park, specifically crashes involving curvature and involvement in crashes where clear zones are poor, further illustrate that unfamiliarity with a road and/or area presents challenges to drivers.

As noted, this work was exploratory, and more detailed analysis is necessary before any definitive conclusions can be drawn. However, it does indicate that approaches to address tourist drivers and their unfamiliarity with an area should be considered to proactively address crashes. For example, additional/improved signing may need to be considered. Information targeted toward familiarizing drivers with the roads in the area they will be visiting should also be considered. Such information could be added to park websites and maps to reach visitors before they arrive and while they are planning their visit.
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