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An Evaluation of Wrong-Way Crashes from Highway Ramps in Kansas, USA

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Abstract

Wrong-way crashes on limited access highways continue to be a serious problem for state highway agencies and communities. These crashes are more likely to result in fatalities or serious injuries than other traffic incidents, due to vehicles traveling at high speeds, often involved on a roadway with limited vertical space and time to avoid a crash. This research study focused on wrong-way crashes that occurred on highways in the State of Kansas. Although these crashes represent a very small portion of crashes, wrong-way crashes were found to have a higher rate of fatalities and injuries as compared to other crash types. Using ten years of crash data, it was found that a typical wrong-way crash occurred under no adverse weather conditions, at a non-intersection location, in daylight or with streetlights present, does not involve alcohol or drugs, and involves a fatality or injury. A cumulative logit model was developed to identify significant characteristics of wrong-way crashes. The model indicated that drivers under the influence of alcohol or drugs was found to be a significant in both fatal and injury wrong-way crashes. It was also found that certain lighting conditions were also significant, along with use of safety equipment and drivers over the age of 55 years old. Additional research is needed to further investigate wrong-way crashes and their causalities in Kansas on other roadway facilities including rural at-grade divided intersections.

Keywords: Wrong-way driving, interstate on-ramps, crash analysis, odd-ratio, regression statistical model

1. Background

1.1. Definition of wrong-way driving

The National Transportation Safety Board (NTSB) defines wrong-way driving as vehicular movement in or along a travel lane in a direction that is opposing the legal flow of traffic (NTSB, 2012; Tamburri, 1965; Tamburri and Theobald, 1965). The NTSB investigated the NTSB analysis of Fatality Analysis Reporting System (FARS) data from 2004 to 2009 which showed that in the United States that approximately 50% to 75% of wrong-way crashes and nearly 60% of fatal crashes were due to a driver impaired by alcohol based on 357 fatal wrong-way crashes out of a possible 218,813 fatal crashes over the time period. It was also found that wrong-way crashes occurred more often at night with approximately 78% of fatal crashes occurring between 6:00 p.m. and 6:00 a.m., with a significant number of these occurring on the weekend (NTSB, 2012). Within the state of Kansas from 2005 to 2015, 35% of wrong-way crashes involved alcohol or drugs, and 59% occurred between the hours or 6:00PM and 6:00AM. Even though wrong-way crashes tend to be rare and random events even for crashes, the sequence of events leading up to and results of these crashes tend to involve multiple vehicles which result in at least one serious injury or fatality making identification of the vehicle point of entry and countermeasure deployment complicated for state highway agencies on specific roadway types, particularly interstate highways.

1.2. Review of Previous Research

A significant breadth of literature exists relating to wrong-way crashes. Studies were first conducted in the 1960s and 1970s, and then again in the 2000s as states moved toward the Federal Highway Administration's (FHWA) Towards Zero Death vision of eliminating fatal and serious injury crashes on the U.S. roadway system (FHWA, 2017). The causes leading up to a wrong-way crash have been investigated and although trends appear in the literature (for both interstates and divided and undivided highways), collecting crash data at the scene of a wrong-way crash, particular on an interstate (limited controlled roadway facility) can be complicated and incomplete due to limited information on the crash sequence of events.

Previous studies have indicated that a driver under the influence of alcohol and/or medication was a significant influence on a wrong-way crash. Braam (2006) found that approximately 43% of wrong-way crashes and 53% of fatal wrong-way crashes in North Carolina (2000 to 2005) were found to involve the driver was under the influence of alcohol. Similar results were also reported by Zhou et al. (2013 and 2014) where wrong-way crashes in Illinois were invested (2004 to 2009) in which the research team found that half of wrong-way driving crashes involved alcohol-impaired drivers. Finally a study by Lathrop et al. (2010) investigated 49 medical files from 2004 to 2009 in New Mexico and found that approximately 60% involved alcohol.

Research has also invested driver age and gender that were associated with wrong-way crashes. Conner et al. (2003), Zhou et al. (2012), and Fisher and Garcia (2016) all noted that male drivers were found to be more common in analyses performed in Texas, Alabama, and Florida with males representing over 60% of the crashes. Research has also indicated drivers that are in wrong-way crashes tend to be over 65 years of age (Braam 2006, Cooner et al. 2003, Zhou et al. 2013). However, Fisher and Garcia (2016) found that drivers between drivers under the age of 21 were also found to be involved in wrong-way crashes. Jalayer et al. (2017) and Pour Rouholamin et al. (2016) also found a wrong-way crash relationship between older drivers, under the influence, and at night having the greatest risk of driving the wrong-way. Previous research has also found that wrong-way driving tends to occur on weekends (Howard 1980), during night time hours (Fisher and Garcia, 2016), poor visibility due to roadway geometry (Copelan 1989).

The research team also identified literature that investigated roadway geometry in wrong-way driving crash experience. Although limited in number, researchers have noted that cloverleaf interchanges were found to have the lowest number of wrong-way crashes in Illinois (Zhou et al. 2014 and Howard 1980) as the number of potential left turning movements are eliminated. Copelan 1989 noted that partial interchanges experienced wrong-way driving incidents in Atlanta with a lack of lateral separation between the off and on-ramp entrances and exits. Parsonson and Marks (1979) and Rinde (1978) noted that half-diamond interchanges are conducive to wrong-way incidents due to a single exit in which drivers may confuse as a highway entry point.

As stated previously, a limited number of wrong-way related research studies have been conducted. However, with innovations in interchange design, differing vehicle characteristics, and an increase rate in serious injury and fatal crashes, the need to continue investing wrong-way driving and developing countermeasures is necessary.

1.3. Existing Guidance in the MUTCD and Countermeasure Analyses

Guidance on preventing wrong-way crashes on various types of roadways using signs, pavement markings, and signalized intersection control are defined in the Manual on Uniform Traffic Control Devices (MUTCD). When it comes to limited access highways and preventing wrong-way driving, Section 2B.41 of the MUTCD specifically addresses wrong-way traffic control at interchange ramps, including a standards section with guidance and two optional sections with guidance. Standards for wrong-way traffic control consists of at least one ONE WAY sign for each direction of travel where an exit ramp intersects a crossroad (MUTCD, 2009).

Additionally, at least one DO NOT ENTER sign must be placed near the downstream end of the exit ramp in full view of the driver mistakenly entering from the crossroad, and at least one WRONG WAY sign must be placed on the exit ramp facing a driver traveling in the wrong direction. Freeway entrance signs or additional ONE WAY and WRONG WAY signs and wrong-way arrow pavement markings or lane-use arrow pavement markings could be added to supplement standard markings (MUTCD, 2009). Guidance for these additional markings suggests that additional ONE WAY signs should be used if the interchange design does not clearly indicate the direction of traffic. Another option allows interchange designers to use engineering judgment to identify if a special need exists and use warnings, devices, or prohibitive methods as necessary.

However, the research team noted that the MUTCD cannot account for all possible roadway conditions, or recognize driver comprehension when providing guidance for wrong-way driving incidents and crashes that may occur. Research studies have also focused on wrong-way driving countermeasures that were designed to enhance warning beyond guidance found in the MUTCD.

Pour-Rouholamin et al. (2015) and Zhou (2014) used survives based on the first National Wrong-way Driving Summit investigate wrong-way driving countermeasures used by state highway agencies. The researchers noted ten physical countermeasures from five state highway agencies along countermeasures related to education, enforcement, and emergency management services (EMS). Pour-Rouholamin et al. (2015) reported through crash analysis that adding a second WRONG-WAY sign, increasing the size of the sign, and lowering the mounting height reduced wrong-way driving incidents in California by 90%. It was also found in the same study that adding LED lighting to WRONG-WAY and DO NOT ENTER SIGNS on Texas highways resulted in a 30% reduction in wrong-way driving incidents. Finally, it was found that adding additional pavement markings at known wrong-way driving incident locations in Texas reduced incidents by 40%.

Finley et al. (2014) investigated the effectiveness of wrong-way driving countermeasures in Texas. Countermeasure effectiveness was evaluated using two closed-course driving studies to investigate how alcohol contributed to a driver's understanding of a sign's message. Additionally, the study investigated where drivers tend to glance while intoxicated. Approximately 30 drivers were used for the study and an eye tracking device was used to collect data under varying blood alcohol content (BAC) levels ranging from 0.00 g/dL to 0.12 g/dL. One study found that drivers were found glancing toward the front of the vehicles towards the ground rather than towards the sides of the roadway. The second study investigated the effectiveness of WRONG WAY sign enhancements as well as pavement markings. Sign enhancements included LED illumination, retroreflective pole tape, sign size, and mounting location. Significant findings of the study found that increasing the size of the sign with retroreflective pole tape or signs with LED illumination were found to be effective. Additionally, it was found that lowering the mounting height of the sign was not as effective at capturing the driver's attention.

2. Research Objective

Motor vehicle crashes have a significant economic impact on the State of Kansas every year, it was reported that this loss was approximately five billion dollars in 2015 (KDOT, 2015), with each fatal crash costing approximately four million dollars. While wrong-way crashes on divided highways are a relatively small percentage of the total number of crashes (typically less than 0.05%), these crashes account for approximately 2% of all traffic fatalities. Divided interstate wrong-way crashes are unique in that access to the roadway is restricted to on- and off-ramps and both signalized and un-signalized interchanges.

A stated in the review of literature, wrong-way crashes have been found to be more serious when higher speeds are involved. Divided limited access highways are typically high-volume roads connecting major cities with one other and the rest of the United States. These roadways usually have two or more travel lanes in each direction with either a physical barrier between the lanes, such as a concrete barrier or guardrail, or a wide grass or gravel median. Entrances to divided highways are normally controlled by interchanges using signs or traffic control devices as described in the MUTCD. Many different types of interchanges are currently in use throughout the United States including diamond, partial cloverleaf, and clover leaf to name a few.

Since access is restricted to a few locations along an interstate, countermeasures for mitigating wrong-way crashes can be better targeted (e.g. signs, LED lights, pavement markings, or ITS solutions). In order to determine proper countermeasures to abate these crashes and prevent near-miss events, crash causes and specifically the sequence of events need to be determined. The objective of this study was to conduct a statistical analysis through descriptive statistics and the development of a model to determine which variables, if any, are significant to wrong-way crashes based on Kansas crash data. Once significant variables are identified, recommendations could be made for effective countermeasures to the Kansas Department of Transportation (KDOT) in a future phase of the research project.

3. Empirical Design

3.1. Wrong-way crash data source

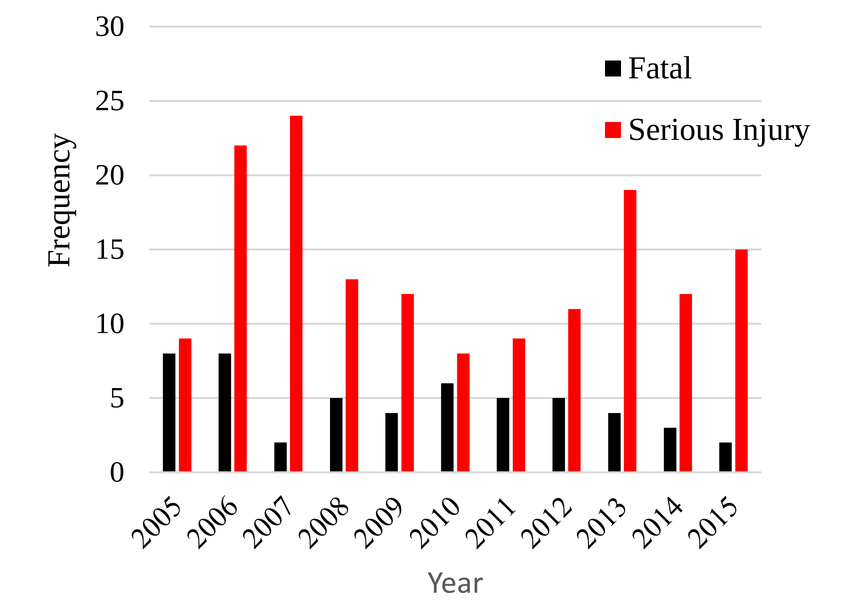
Data on wrong-way crashes requested from KDOT came from the Kansas Crash and Analysis Reporting System (KCARS). Information in the KCARS system comes from accident reports filled out by law enforcement personnel for the Kansas Law Enforcement Reporting (KLER) system. Law Enforcement Officers use KDOT Form 851 Rev. 1-2009 which is a 12-page form filled out by selecting an option that best fits the situation. Data on wrong-way crashes occurring on divided highways in the state of Kansas were provided in an Excel form with further data provided in an Access data file.

A preliminary study indicated a large number of wrong-way crashes in Kansas occurred on state highways with no median or barrier between the different travel lanes. Since cross-centerline crashes typically results from vehicles drifting over the centerline, passing maneuvers or other events not related to traveling in the wrong direction on a highway, crash data were limited to wrong-way crashes on divided highways. Since wrong-way crashes are typically a rare and random event with very few occurring each year, ten years of crashes data (2005 to 2015) were investigated. Initial examination of the data showed crashes that had occurred on divided highways with at-grade intersections, as well as those with ramps and interchanges. Divided highways with at-grade intersection entrances were a small sub-set of the data and had different characteristics than crashes that occurred on divided highways with ramps. Crashes occurring on divided highways with at-grade-intersections were analyzed separately to get an accurate analysis of this type of wrong-way crash, but not included in this study.

3.2. Descriptive statistics

The remaining 372 wrong-way crashes were statistically analyzed, and descriptive statistics created. Initial examination of the data showed that of the 372 crashes, 52 were fatal crashes and 154 injury crashes, for the result of 55% of wrong-way crashes involving a fatality or serious injury. Typically, fatal and injury crashes compromise of approximately 22% of all crashes in the state of Kansas (KDOT, 2015), and nationally about 27% (NHTSA, 2014). Figure 1 shows the relationship between fatal and injury crashes, and total number of serious crashes.

As shown on the left side of Figure 1, the graph for fatal and injury crashes has regular peaks and valleys. An interesting point with this chart is the relationship between fatal and serious injury crashes. Both graphs have peaks and valleys, as would be expected, but what stands out is location of the peaks and valleys for both categories. As fatal crashes reach a valley, serious injury crashes reach a peak. Then as fatal crashes begin the upswing to the peak, serious injury crashes begin their downswing, reaching the low point for serious crashes while at the same time reaching the peak in fatal crashes. At this point, fatal crashes begin to decline again, while serious injuries begin to climb again. This indicates the total number of serious crashes has remained fairly constant over the years. The total number of serious crashes ranges from 14 to 30; the overall average number of serious crashes is almost 19 crashes per year.



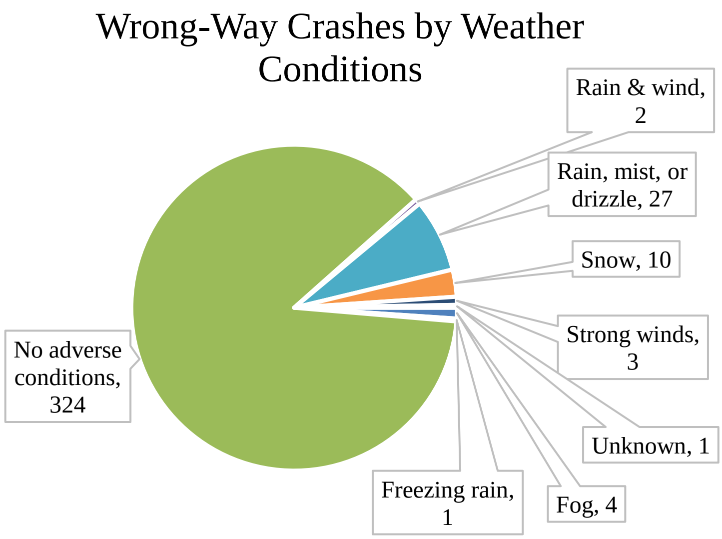
Year	Total No. Crashes
2005	47
2006	56
2007	48
2008	39
2009	33
2010	21
2011	25
2012	24
2013	30
2014	22
2015	27

Fig. 1. Wrong-way crash frequency and severity for 2005 to 2015

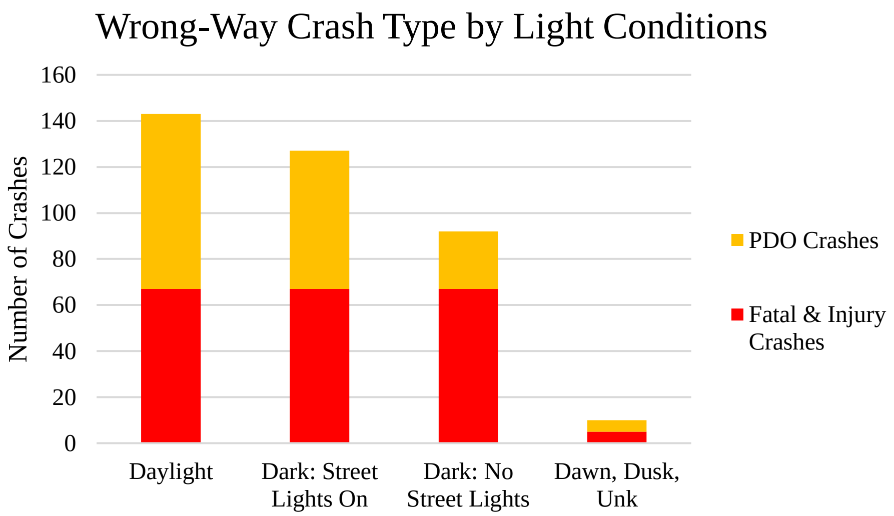
The number of all types of wrong-way crashes shows similar overall peaks and valleys, but an overall downward trend can be seen in the table on the right side of Figure 1. The average number of wrong-way crashes over the evaluation period was almost 34 crashes per year. Serious crashes, defined as fatal crashes and crashes with a reportable injury, make up an overall average of almost 56% of total wrong-way crashes. According to the NTSHA, the percentage of serious crashes has decreased over the years from 33% to just under 28% (NHTSA 2014). Overall trend of wrong-way crashes in Kansas seems to be declining, dropping from 47 in 2005 to 27 in 2015. However, in 2005, the percentage of serious crashes was 36%, but since then the percentage of serious crashes has increased to more than 60% with a peak as high as 77%.

Further examination of descriptive statistics showed several other interesting graphs. Figure 2a shows the reported weather conditions during each crash event. What stood out from this graph is the extremely large portion of crashes occurring with no adverse weather conditions. In fact, there were no adverse weather conditions present in 324 or 87% of wrong-way crashes. Absence of any adverse weather conditions to this degree does seem unusual, as one would expect a larger occurrence of adverse weather conditions such as rain, snow, wind, or fog. According to data from the NTSHA, this is actually in line with national crash statistics where 86% of crashes occur under no adverse weather conditions (NTSHA 2014).

Figure 3a shows data concerning each light condition option available during the crash. Due to small numbers of crashes, dawn, dusk, and unknown times were combined into one category. This graph is not as skewed as some of the others, being as it is a bit more evenly distributed between daylight, dark with streetlights on, and dark with no streetlights. However, what is interesting about this graph is that the number of fatal and injury crashes is the exact same across all light conditions — daylight, dark with streetlights, and dark with no streetlights. In contrast to this, the total number of wrong-way crashes decreases when going from daylight to dark, with streetlights to dark, and with no streetlights. In other words, as the amount of light available decreases, so does the number of wrong-way crashes. What does increase is the percentage of wrong-way crashes that result in a fatality or injury. During daylight hours, 46.9% of wrong-way crashes result in either a fatality or an injury. When it is dark with streetlights on in the area, the percentage of wrong-way crashes that result in a fatality or an injury increases to 52.8% or just over half. However, when it is dark out and there are no streetlights present, the percentage of wrong-way crashes resulting in a fatality or an injury jumps to 72.8%, or almost three out of every four wrong-way crashes occur at night with no streetlights.

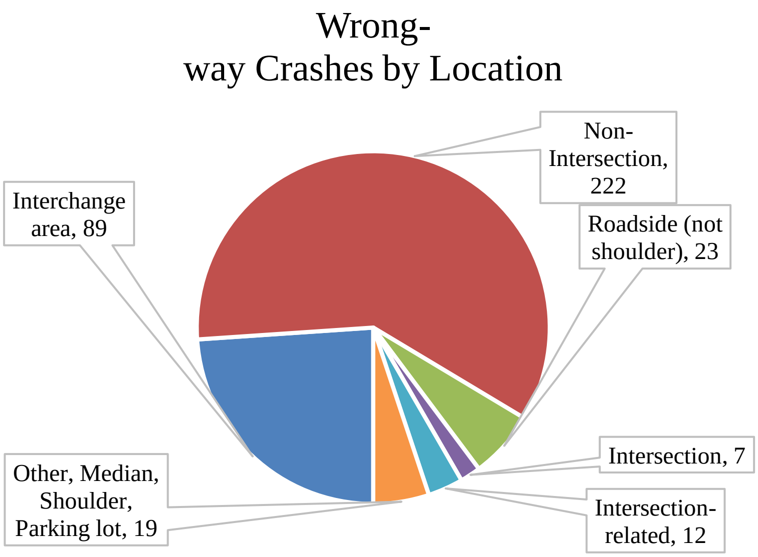


(a)

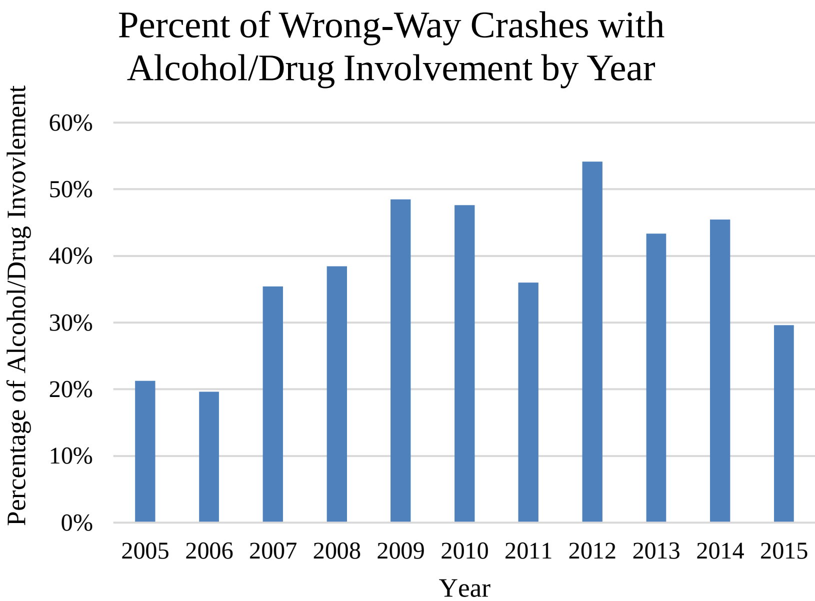


(b)

Fig. 2. (a) Wong-way crashes by reported weather condition; (b) Wrong-way crash by reported lighting condition and severity



(a)



(b)

Fig. 3. (a) Wong-way crashes by reported by location; (b) Wrong-way crashes with reported drivers under the influence

Figure 3a shows the location on the highway of each crash, indicating the majority of wrong-way crashes, 60%, occur at non-intersections, or away from entrance and exit ramps. This is a problem in several ways. First, it indicates drivers of wrong-way vehicles are getting past all signs indicating they are driving in the wrong direction without either realizing they are traveling in the wrong direction or without correcting themselves and turning around. The second problem is the further they travel the wrong-way down the road, the greater the chance of encountering vehicles traveling the proper direction on the road. While the longer they travel does give authorities more time to stop them, it also increases the chances of a crash. Perhaps the more concerning part, in terms of statistical evidence, is that not every wrong-way incident ends up as a wrong-way crash. Some correct themselves and start going the correct direction, and others exit the interstate at other exits. Determining the exact number of wrong-way incidents would go a long way to assisting in determining effective countermeasures.

Figure 3b shows the percentage of wrong-way crashes involving alcohol or drugs by year. It shows alcohol/drug involvement rose from a low of 20% in 2006, to a high of 54% in 2012. While the high figure is close to the national percentage of nearly 60%, it is still below it. Year 2012 also represents the only time span where more than 50% of wrong-way crashes involved alcohol/drugs. Since then, the percentage has trended down, dropping to 30% in 2015. Overall, alcohol and drugs are involved in 35.5% of wrong-way crashes or an average of 12 per year. This is not an overly large number, especially when considering the roughly 60,000 crashes per year in the state of Kansas, with just over 2,300 of those involving alcohol.

4. Analysis

Information on the 372 wrong-way crashes was analyzed for statistically significant characteristics to the 95% confidence level. We chose to examine data based on crash type — fatal crash, injury crash, and property damage only (PDO) crash. Since our response has three categories, the cumulative logit model was chosen to fit our data. This allowed the model to compare fatal crashes to injury and PDO crashes, and injury crashes to PDO crashes at the same time. Utilizing the SAS software for analysis where “proc logistic” is used, a “glogit link” was added to ensure the link function in the model was the log link. The basic model has the form:

$$log(\hat{y}) = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \cdots + \hat{\beta}_k X_k$$

Where: $\hat{y}$ = response fatal or injury crash
$\hat{\beta}_k$ = estimates
X = parameters
k = number of parameters

The method to determine significant model parameters used was forward selection. The first step was to run the model using all possible parameters of a wrong-way crashes individually. The parameter with the smallest p-value was added to the model. After the initial analysis, parameters were individually added to the model keeping the parameter with the smallest p-value. This continued until all parameters remaining were higher than the chosen value of $\alpha=0.05$.

RESULTS

The final model developed was found to have four significant parameters. Results of the final model are shown in Table 1. The parameters significant to the 95th percentile were “Safety Equipment”, “DUI”, “Age Category”, and “Light Conditions”. Safety Equipment reports which safety devices were used or deployed during the crash such as airbags, lap seat belts, shoulder belts or combinations of those safety devices. The parameter DUI represent the combined categories of drug and alcohol involvement, which are tracked separately by KDOT. Age Category represents the age of the driver who was traveling the wrong-way. These categories were the same parameters used in the NHTSA Traffic Safety Facts, with the exception of category number one, which combines all ages below fifteen years old, since they typically are not of legal age to drive (NHTSA 2014). Light Condition refers to the light at the time of the crash and is notated by daylight, dark with streetlights on, dark with no streetlights, dawn and dusk. Note the degrees of freedom were double than what they normally would be. Since the response “y” has three levels and the model was conditioning on two cases, PDO and injury versus fatal and PDO versus injury, degrees of freedom were doubled. Reference conditions for the model were “no alcohol involvement” for DUI, “shoulder” and “lap belt” use for safety equipment use, “ages 35 to 44” for the age category and “dark with no streetlights” for light conditions.

Table 1. Final developed model

Summary of Forward Selection					
Step	**Effect Entered**	**DF**	**Number In**	**Score Chi-Square**	**Pr > ChiSq**
1	**SafetyEquip**	18	1	127.1513	<.0001
2	**DUI**	2	2	14.4266	0.0007
3	**AgeCat**	16	3	33.0382	0.0073
4	**Light**	10	4	22.029	0.015

The final model for the data was:

$$log(\hat{y}) = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \hat{\beta}_3 X_3 + \hat{\beta}_4 X_4$$

Where: $\hat{y}$ = *fatal or injury crash*
$\hat{\beta}_0$ = *intercept*
$\hat{\beta}_k$ = *estimate for k parameter*
X_1 = *alcohol/drug involvement (DUI)*
X_2 = *safety equipment (SafetyEquip)*
X_3 = *age of wrong-way driver (AgeCat)*
X_4 = *light condition (Light)*

Significant parameters were found to be not the same for injury as for fatal crashes. While alcohol/drug involvement (DUI) and safety equipment were significant for both fatal and injury crashes, as can be seen in Table 2, light conditions were found to have different characteristics that were significant in injury and fatal crashes, and the age category was significant for only fatal crashes.

Table 2. Individual parameter estimates and odds ratios for injury crashes

Analysis of Maximum Likelihood Estimates				**Odds Ratio Estimates**		
Parameter	**Estimate**	**Standard Error**	**Pr > Chi Sq**	**Point Estimate**	**95% Wald Confidence Limits**	
Intercept	-0.4191	0.4516	0.3534			
DUI: Under Influence vs Not under influence	**0.8264**	**0.3244**	**0.0108**	**2.285**	**1.21**	**4.316**
Light: Daylight vs Dark with No Streetlights	-0.5589	0.3738	0.1349	0.572	0.275	1.19
Light: Dark with Streetlights vs Dark with No Streetlights	**-0.704**	**0.3528**	**0.046**	**0.495**	**0.248**	**0.988**
SafetyEquip: None vs Shoulder/Lap belt	**1.4896**	**0.4397**	**0.0007**	**4.436**	**1.873**	**10.501**
SafetyEquip: Airbag & Shoulder/Lap belt vs Shoulder/Lap belt	**1.8543**	**0.4628**	**<.0001**	**6.387**	**2.578**	**15.823**
SafetyEquip: Unknown vs Shoulder/Lap belt	0.2198	0.3917	0.5746	1.246	0.578	2.685
AgeCat: 55 to 64 vs 35 to 44	0.4206	0.6402	0.5112	1.523	0.434	5.341
AgeCat: 65 to 74 vs 35 to 44	-0.1826	0.6571	0.7811	0.833	0.23	3.02
AgeCat: >74 vs 35 to 44	0.5929	0.6301	0.3467	1.809	0.526	6.221

What is of interest is the estimation of odds ratios for each parameter shown in Tables 2 and 3 for injury and fatal crashes respectively. An odds ratio that are greater than 1 indicate increased odds for the reference category when compared to the comparative category, while an odds ratio less than 1 indicates increased odds for the comparative category when compared to the reference category. The farther from 1 the odds ratio is, the stronger the association is between the characteristic and the severity of the crash.

For wrong-way crashes resulting in an injury crash as shown in Table 2, the chance of being involved in an injury crash was found to be 2.285 times more likely for drivers under the influence of alcohol / drugs when compared to those drivers not under the influence of alcohol / drugs. For wrong-way crashes and light conditions, the chance of being involved in an injury crash was found to be 2.02 times more likely when it is dark with no streetlights when compared to dark with streetlights on. For wrong-way crashes and the use of safety equipment the chance of being involved in an injury crash for drivers using no safety equipment was 4.436 times more likely and an airbag only was 6.387 times more likely when compared to using a shoulder and lap belt.

Significant parameters for wrong-way fatal crashes are shown in Table 3. For these crashes, the chance of being involved in a fatal crash was 5.649 times higher for a driver who was under the influence of alcohol / drugs when compared to drivers not under the influence of alcohol / drugs. For wrong-way crashes and light conditions, the chance of being involved in a fatal crash was 6.579 times more likely when it was dark with no streetlights when compared to dark with streetlights on.

Table 3. Individual parameter estimates and odd rations for fatal crashes

Analysis of Maximum Likelihood Estimates				**Odds Ratio Estimates**		
Parameter	**Estimate**	**Standard Error**	**Pr > Chi Sq**	**Point Estimate**	**95% Wald Confidence Limits**	
Intercept	-2.9998	0.819	0.0002			
DUI: Under Influence vs Not under influence	**1.7316**	**0.5738**	**0.0025**	**5.649**	**1.835**	**17.394**
Light: Daylight vs Dark with No Streetlights	-1.0092	0.5702	0.0767	0.365	0.119	1.114
Light: Dark with Streetlights vs Dark with No Streetlights	**-1.8831**	**0.5457**	**0.0006**	**0.152**	**0.052**	**0.443**
SafetyEquip: None vs Shoulder/Lap belt	**2.8571**	**0.6237**	**<.0001**	**17.411**	**5.128**	**59.12**
SafetyEquip: Airbag & Shoulder/Lap belt vs Shoulder/Lap belt	**2.8755**	**0.6567**	**<.0001**	**17.734**	**4.896**	**64.235**
SafetyEquip: Unknown vs Shoulder/Lap belt	1.104	0.7195	0.1249	3.016	0.736	12.358
AgeCat: 55 to 64 vs 35 to 44	**1.987**	**0.9569**	**0.0378**	**7.293**	**1.118**	**47.578**
AgeCat: 65 to 74 vs 35 to 44	**1.6258**	**0.8977**	**0.0701**	**5.082**	**0.875**	**29.526**
AgeCat: >74 vs 35 to 44	**2.7945**	**0.8783**	**0.0015**	**16.354**	**2.924**	**91.451**

While it is not significant to the 95th percentile, it is worth noting that the only additional characteristic that was significant at the 90th percentile was the light condition dark with no streetlights when compared to daylight. However, for wrong-way crashes and light conditions, the chance of being involved in a fatal crash was 2.740 times more likely when it is dark with no streetlights when compared to daylight. For wrong-way crashes and safety equipment use, the chance of being involved in a fatal crash was 17.41 times higher for a driver use no safety equipment and 17.73 times higher for a driver using an airbag only when compared to drivers using a shoulder and lap belt. Age was only significant as a characteristic with fatal crashes. For wrong-way crashes, a driver's chance of being involved in a fatal crash is 7.29 times more likely for drivers between the ages of 55 and 64 and 16.35 times more likely for drivers older than 75 years old. It is also worth noting that, while only significant to the 90th

percentile, drivers between the ages of 65 and 74 were 5.08 times more likely to be involved in a fatal crash when compared to drivers between the ages of 35 and 44.

5. Discussion and Significant Findings

Data shows that wrong-way crashes are a very small subsection of crashes in Kansas, typically less than 0.05% of all crashes. Yet they are responsible for 2% of all traffic fatalities. From 2005 to 2015, 372 identified wrong way crashes occurred on Kansas divided highways, 52 fatal crashes and 154 injury crashes. Typically, fatal and injury crashes compromise 22% of all crashes in Kansas, but for wrong-way crashes, the percentage of fatal and injury crashes is about 55%, a much larger number. Wrong-way crashes are typically head-on crashes occurring at interstate highway speeds. It is obvious why they are significantly more serious than typical crashes.

From the wrong way crash data analyzed, a typical crash in Kansas occurred with no adverse weather conditions (87%), at a non-intersection location (60%), in daylight (38%) or with streetlights (34%) and does not involve alcohol or drugs (65%) yet involves a fatality or injury (55%). Nationally, 60% of wrong-way crashes involve alcohol and 78% occur at night, which is in contrast to crashes that occurred in Kansas. With the overall trend of wrong way crashes declining, the percentage of fatal and injury crashes is increasing. While vehicle crashes are rare and random events which many times results in minimal damage, fatal and injury crashes have a significant impact on a state and local jurisdiction economy if roadway countermeasures are demanded.

Using a cumulative logit model to the 95% confidence level, data were examined for statistically significant characteristics of both fatal and injury crashes. Utilizing a forward selection process, significant parameters were determined to be alcohol/drug involvement (DUI), light conditions, safety equipment use and age. While age was found to be significant for only fatal crashes, the other characteristics were found to be significant for both fatal and injury crashes. Alcohol /drug involvement was found to be significant with both fatal and injury crashes. Dark with no streetlights on was found to be significant as well as use of airbag with lap and shoulder belts and use of no safety equipment. Age categories from 55 to 64 and over 74 years old were found to be significant to the 95th percentile and drivers age 65 to 74 were found to be significant to the 90th percentile.

The odds ratios for wrong-way crashes in Kansas show similar trends to national statistics. Nationally most wrong-way crashes occur at night and involve alcohol / drug impaired drivers and from 6 pm to 6 am (NTSB 2012). The characteristics that were significant for both fatal and injury crashes were drivers under the influence of alcohol / drugs and light conditions of dark with no street lights. However, looking at the descriptive statistics reveals a different outlook where most of the wrong-way crashes occur in daylight and dark with streetlights on and impaired drivers are involved in 35% of wrong-way crashes. Other studies have also found that age can be significant. A study conducted in Illinois found that older drivers were significant (Zhou, 2012). A study in Alabama found that drivers older than 65 were significant in wrong-way crashes (Pour-Rouholamin, 2016).

When looking at the odds ratios for injury and fatal crashes another thing is significant. For each characteristic the odds ratio for fatal is larger than the odds ratio for injury crashes. This means that for each characteristic, while the chance of being involved in an injury crash is more likely, there is a bigger chance of being involved in a fatal crash. While there is not much that can be said for certainty based on a statistical study, a conclusive comparison can be made with the DUI, Dark with no streetlights, None and Airbag only characteristics. Since the ratios increase for each of these, it can be concluded that crashes under these circumstances are more serious.

Although this study was limited to understanding crash causation, the statistical model does indicate that a targeted countermeasure such as lowering the WRONG-WAY sign height may be effective at night and for drivers under the influence. Additionally with the lowering cost of ITS solutions, an eliminated WRONG-WAY sign and vehicle detection would also be an excellent countermeasure. The research team plans to continue this study through the evaluation of low-cost countermeasures now that a base-line study has been conducted and a before-after analysis can easy be performed. Additionally, a significant limitation of this study was found to be the reliability of the crash data. As stated previously and by other researchers, understanding the exact location and entrance of a wrong-way driver onto the interstate system is complicated. The research team believes additional research in the area of crash coding, vehicle detection, and possible interchange geometric improvement are needed to reduce or lower the severity of wrong-way crashes.

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