DEER VEHICLE ACCIDENTS IN KANSAS:

SPATIAL DISTRIBUTIONS AND TRENDS

By

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CHAPTER I

INTRODUCTION

Deer Vehicle Accident History

Deer vehicle accidents (DVAs) are a serious problem throughout the United States. Bissonette and Romin (1996) estimated that 500,000 DVAs occurred nationally in 1991. Since 1991, yearly DVA counts have risen to over 1.5 million, but actual numbers may be much higher, since many are never reported (Conover et al., 1995; Curtis and Hedlund, 2005). While increased DVA rates represent a problem nationally, their impact varies from state to state. In 1991, Bissonette and Romin (1996) surveyed 29 states and found that 26 had experienced increased DVAs since 1982. Of these states, the overall rates of increase varied, as did with how state agencies viewed the problem (Bissonette and Romin, 1996). DVAs pose a problem for state transportation departments, since they are responsible for keeping motorists safe (Messmer and Sullivan, 2003). State wildlife departments, however, are responsible for managing deer populations to the max benefit of the states' residents and generally view larger deer populations as beneficial.

To justify researching DVA occurrences, Decker et al. (1993) and Ament et al. (2009) recommended comparing the costs of DVAs to the benefits of deer as a natural resource. While researchers have studied DVAs in multiple eastern and Midwestern states (Bellis and Graves, 1971; Anderson, Grund, and Nielsen, 2003; Gonser and Horn, 2007), central states such as Kansas, Nebraska, Missouri, and Oklahoma have remained relatively un-studied, so a study of this region could be beneficial. The question, then, is whether one of these states has a greater DVA problem than the others so it would warrant having its own study.

Comparison of Central Great Plains States

In 2002, of five states, (Table 1), Kansas had significantly higher DVA rates and a greater need for state-scale study. The difference between Kansas' 2002 DVA rates and the next highest, Nebraska, was 110 DVAs per 100,000 people (all subsequent references to DVA rates will be per 100,000 people). Kansas' DVA rates were even greater when compared to the other states, averaging a difference of 250 or more. This disparity also appeared in 2006. If these data are reliable, then obviously Kansas has the region's worst problem with DVAs.

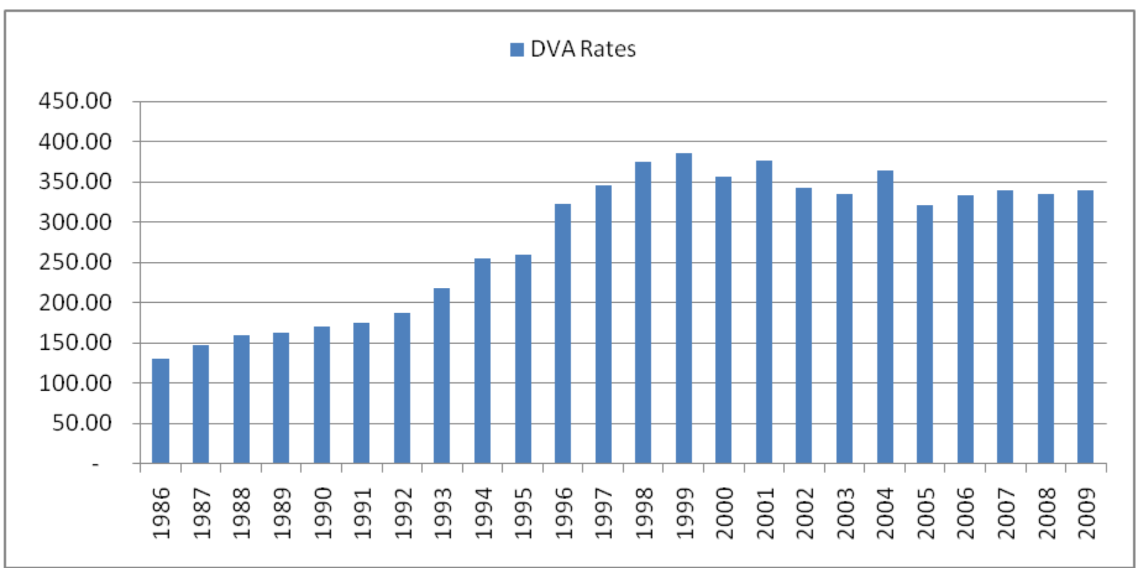
Table 1: Comparison of 2002 and 2006 DVA Rates

State	2002 DVAs/100,000 pop.	2006 DVAs/100,000 pop.
Colorado	97.27	42.05
Kansas	343.23	341.6
Missouri	63	50.88
Nebraska	233.51	203.82
Oklahoma	52.8	57.72

Sources: CDOT, 2010; NDOR, 2010; KDOT, 2010; MODOT, 2010; OHSO, 2010

Upon closer inspection, one finds that DVA rates have soared in Kansas in recent decades, from 128 in 1986 to 384 in 1999 (Figure 1). Since then, annual DVA rates have hovered around 350 (KDOT, 2010).

Figure 1: Kansas DVA Rates 1986 to 2009



Sources: KDOT, 2010; US Census Bureau, 1980; US Census Bureau, 1990; US Census Bureau, 2000

The economic cost resulting from these high DVA rates has placed a large burden on Kansas and its people. DVAs in 2008 caused an estimated $64,787,100 in property damages, primarily to automobiles. Six people also died as the result of DVAs in 2008 and applying a monetary value to loss of life is difficult (KDOT, 2008).

Research Problem

A state-scale analysis of DVAs in Kansas is warranted because Kansas has significantly higher DVA rates than surrounding states, its DVA rates have risen in recent decades, and DVAs account for serious losses of lives and property each year. Better decision-making could be used to rectify the DVA problem with an enhanced understanding of the following two research questions.

1. What are the primary spatial factors influencing the distribution of DVAs in Kansas?
2. Have these factors changed over time?

Discerning significant spatial factors related to DVAs will assist mitigation techniques implemented by state transportation planners.

This study seeks to identify which spatial factors best account for variations in the distribution of DVAs in Kansas. Spatial factors that may be influential include land cover, human population density, road type, and bridge density, to name a few. Researchers have found similar factors to be influential in other states, so it is likely they could be affecting DVA distributions in Kansas

(Finder, Roseberry, and Woolf, 1999; Iverson and Iverson, 1999; and Seiler, 2004). These spatial factors were used to identify a list of variables (Tables 2, 3, and 4 in the methodology chapter) to be examined in this study.

An areal study using multivariate regression analysis was deemed the best approach for answering the research questions (an in-depth justification for why this is the case is provided later). Additionally, multiple years are examined to study the patterns over time. The time period being examined is 1992 to 2008, a period of increased DVA rates. The years 1992, 2001, and 2008 were chosen as specific years to be studied within this overall period. These years were chosen primarily due to the availability of data. Studying these years should help reveal how DVA patterns and factors may change with time. While this study specifically concentrates on Kansas, the methods used can be applied to Kansas' neighboring states and others throughout the United States.

CHAPTER II

REVIEW OF LITERATURE

DVA Research Methods

A common theme in DVA research has been the identification of factors associated with DVA occurrences. This allows for modeling of DVA events and coordinating mitigation (Bissonette, Kassar, and Cook, 2008). Researchers use two methods to examine DVAs: site studies and areal studies. Site studies examine actual locations of DVAs while areal studies examine aggregate data, such as county-level units.

Site Studies

The site study approach is most commonly used in DVA research and has been around the longest. It represents the majority of literature on DVAs and has been typically implemented by biologists as well as researchers from a variety of other fields. Often a single section of road is the scale of analysis.

Bellis and Graves (1971), Bellis, Lindzey, and Puglisis (1974), Bellis et al. (1975), Ross and McCullough (1976), and Bashore, Tzilkowski, and Bellis (1985) conducted their studies by visiting DVA sites and recording site-specific data. These data included information on the type of road, surrounding vegetation, topography, and other factors present at the accident site. They used this information in conjunction with data from accident reports (time, date, etc.) to identify factors common to DVA sites. These original site studies were less quantitative in their methods and instead could be considered investigations specific to individual sections of road. This method of analysis is important, but also expensive and time consuming.

Bellis and Graves (1971) were some of the first researchers to use the site study approach on DVAs. They examined DVAs along an 8 mile stretch of interstate I-80 in Pennsylvania for 14 months. This method of only examining one road for a limited distance would be continued by researchers for several more years (Bellis, Lindzey, and Puglisis, 1974; Bellis et al., 1975).

Ross and McCullough (1976) ended the trend of only examining one road per DVA study. They instead researched DVAs in southern Michigan for 10 counties, which was a significant increase in the overall scope of the research. Ross and McCullough’s study was also one of the first to compare DVAs in regards to different types of highways, which had not been done before (Ross and McCullough, 1976). The next improvement in site study DVA research would not come for another 20 years until the advent of new technology.

The integration of GIS and remote sensing in the 1990s improved DVA site data collection. GIS allowed spatial variables associated with DVAs to be accurately identified and recorded without having to visit the actual DVA site. The benefit of using a GIS approach over the original site study method is that larger study areas could be examined. Instead of just one or two road sections, GIS allowed whole counties to be examined because it made collecting information for the specific sites significantly easier (Finder, Roseberry, and Woolf, 1999; Anderson, Grund, and Nielsen, 2003; Gonser and Horn, 2007; Yarnes, 2008; Campa III, Riley, and Sudarsan, 2009; and Seifert, 2010).

Finder, Roseberry, and Woolf (1999) were some of the first researchers to implement GIS in their study of DVAs in Illinois. Their study worked by integrating accident sites with other data, such as land cover, terrain, and roads. Next, they created a series of buffers around the accident sites, which were used to create cut outs of the other layers. Finder, Roseberry, and Woolf took the information collected from these cut outs and analyzed it to determine what the most common factors were at the accident sites. They then conducted real world field studies to verify the accuracy of the results (Finder, Roseberry, and Woolf, 1999).

Finder, Roseberry, and Woolf’s research demonstrated the benefit of using GIS to study DVAs and almost every later DVA researcher including Anderson, Grund, and Nielsen (2003) and Gonser and Horn (2007) would use similar methods in their own DVA research (Finder, Roseberry, and Woolf, 1999; Anderson, Grund, and Nielsen, 2003; Gonser and Horn, 2007). While the methods of implementing GIS to study DVAs have remained relatively the same, the scales and locations of the research has gradually changed with time.

Anderson, Grund, and Nielsen's (2003) study of DVAs in Minnesota was one of the first studies to apply GIS to a specific problem. They used GIS to examine DVA distributions in regards to urban areas, which had not been done before. After Anderson, Grund, and Nielsen's (2003) study several other scientists including Gonser and Horn (2007) would conduct research directed at studying DVAs in urban environments.

The overall methods used in site study DVA research have remained relatively the same since the implementation of GIS. DVA site study research continues to be done with the same methods and the main differences between the studies are the counties and states in which they are conducted (Yarnes, 2008; Campa III, Riley, and Sudarsan, 2009; and Seifert, 2010).

Areal Studies

While site studies focus on DVA location factors, areal studies compare spatial associations among DVAs and causal factors. Areal studies are conducted at a smaller scale (representing larger areas) than site studies and use aggregate data (Seiler, 2004; Farrell and Tappe, 2007). Aggregate data may include human population, land cover, or roads for areal units, such as counties, deer management units, or some other bounded area.

Iverson and Iverson (1999), Seiler (2004), and Farrell and Tappe (2007) studied DVAs using the areal approach. These studies compared DVA distributions to “DVA factors” identified in site studies as starting points for their models. Areal studies must, necessarily, use quantitative techniques to model DVAs; most commonly this is multivariate regression analysis. Multivariate regression examines the relationships among independent variables relative to a dependent variable (Iverson and Iverson, 1999; Seiler, 2004; Farrell and Tappe, 2007). In DVA research multivariate regression analysis is primarily accomplished by having DVAs as the dependent variable and factors such as human population density, land use, and roads as the independent variables.

Multivariate regression analysis works on the basis of four assumptions. The first assumption is that for every value of an independent variable, all the residuals (errors) averaged together should equal zero. Second, the difference in residual error is equal for each value, known as homoscedasticity. Third, each residual value is independent of the other values. The fourth assumption is that the error values are normally distributed. Scatter plots are often used to evaluate whether the variables meet these assumptions, which must be determined before the final regression analyses are performed. Preliminary regression analyses, however, must be conducted to study the residuals of the models. Once this is done, the regression analysis is performed and the researcher uses the results to identify relationships between the independent variables and the dependent variable (Barber, Burt, and Rigby, 2009).

Multivariate regression analysis is useful for DVA studies because it allows researchers to determine how the independent variables influence the distribution of the dependent variable and to what extent. This means that for DVA studies a researcher can determine how independent such as human population density, land use, and roads affect the distribution of DVAs within a state or some other bounded area (Iverson and Iverson, 1999; Seiler, 2004; Farrell and Tappe, 2007).

Iverson and Iverson (1999) were some of the first researchers to examine DVAs using an areal study. They inspected the county-scale DVA distributions in Ohio for 1995. While site study methods at this time were using GIS to study DVAs, Iverson and Iverson were experimenting with using quantitative techniques to examine much larger areas then previously possible. Iverson and Iverson's method of using multivariate regression analysis would be repeated by Seiler (2004) and Farrell and Tappe (2007).

Seiler (2004) took the methodology used in areal studies further in his research of deer and moose collisions in Sweden. He did this by conducting his analysis at multiple scales (county, district, and parish). Additionally, he examined several different time periods in his study, something which has not been done within North America. Farrell and Tappe's (2007) research on DVA distributions in Arkansas used the same scale and techniques as Iverson and Iverson (1999) and added to the overall body of DVA research using areal studies, which is significantly smaller than that of site studies.

Comparison of Methods

Both site studies and areal studies have their benefits and limitations. One of the drawbacks of conducting a site study is that individual DVA location data are frequently inaccurate or unavailable, requiring researchers to map locations described in accident reports (Finder, Roseberry, and Wolf, 1999). Such an approach is not feasible for this study because of the availability of data.

Areal studies are feasible because most states, including Kansas, record DVAs by county (Iverson and Iverson, 1999; Farrell and Tappe, 2007). Additionally, county-scale analysis conforms to the scale that most state agencies use to mitigate DVAs (Farrel and Tappe, 2007). Furthermore, a study using areal analysis can identify patterns that site studies cannot (Seiler, 2004). Areal analysis is limited, however, by the availability of data, and therefore possible factors implying causation, that one can examine. Site studies are beneficial because they allow identification of factors at individual DVA sites. Indeed, lessons learned from site studies inform areal studies.

Data Examined

Human population density, road type (either two lane highway or four lane interstate), land use, bridges, and deer harvest numbers are variables that previous site studies have identified as significant factors contributing to DVAs. Importantly, no one study has found all variables to be significant, and the results of many seem contradictory.

For example, it is unclear how deer harvest figures (which represent the number of deer killed by hunters in an area) affect DVA rates. While Delger et al. (2008) identified a relationship between deer harvest and DVAs, Iverson and Iverson (1999) and Seiler (2004) found harvest numbers to be unrelated to DVAs. Seiler's results might explain this difference because he found that the significance of harvest numbers and population density often depended on the scale of analysis. Indeed, scale may explain their differing conclusions, or simply be a result of the different environments of the studies.

There is more agreement of the relationship between land cover and DVA occurrence. Bellis, Lindzey, and Puglisis (1974), Bellis et al. (1975), Anderson, Grund, and Nielsen (2003), Gonser and Horn (2007), and Delger et al. (2008) all identified the presence of forest or grassland as affecting DVA rates. Bellis, Lindzey, and Puglisis felt this could be the result of the forested areas hiding deer from a driver's view while the grasslands served as a food source, possibly leading to higher deer concentrations (Bellis, Lindzey, and Puglisis, 1974). Gonser, Jensen, and Wolf (2009) found that planted and cultivated land was another land cover associated with higher DVAs, with the crops possibly serving as a deer food source.

The type of road (whether two lane highway or four lane interstate) is another factor that has been found to be significant by multiple researchers (Ross and McCullough, 1976; Bashore, Tzilkowski, and Bellis, 1985; and Iverson and Iverson, 1999). Bashore, Tzilkowski, and Bellis (1985) indentified two lane highways as having a higher incidence of DVAs than four lane interstates. Other factors, such as the presence of bridges, were only found influential in one study (Danielson, Hubbard, and Schmitz, 2000). These factors provide a useful starting list for this study.

For this study on Kansas, DVA density, highway density, interstate density, bridge density, percent of land used for sorghum, percent of land used for corn, percent of land used for hay, percent of land used for wheat, percent of land protected, deer harvest density, and human population density were chosen as starting variables to be used in the regression analysis. The following paragraphs provide a brief description of each variable including: what the variable represents, where I obtained the data, and any manipulations or transformations I performed to get the data in the format needed.

Highway density, interstate density, bridge density, deer harvest density, and human population density were all chosen because researchers have found these variables influential in DVA distributions (Ross and McCullough, 1976; Bashore, Tzilkowski, and Bellis, 1985; Finder, Roseberry, and Woolf, 1999; Iverson and Iverson, 1999; Danielson, Hubbard, and Schmitz, 2000; Seiler, 2004; Farrel and Tappe, 2007). Percent of land used for sorghum, percent of land used for corn, percent of land used for hay, and percent of land used for wheat were chosen because these variables represent large portions of land use in Kansas. Additionally, these crop variables were chosen because none of the previous studies examined whether individual crops affected DVA distributions. Instead, past researchers such as Iverson and Iverson (1999) grouped all the crops into a single crop variable. Examining the crops individually instead of as one large group could reveal new information on the factors affecting DVA distributions. The percent of land protected was chosen because protected land could affect DVA distributions as the prohibition of hunting on these lands may lead to higher deer densities.

The DVA density variable represents the deer vehicle accident density for each county. I created this variable by taking the total number of DVAs occurring per county divided by the area of the county. The original information for the variable was obtained from the Kansas Department of Transportation (KDOT, 2010).

The highway density variable represents the two lane state and federal highway density for each county while the interstate density variable represents the four lane interstate density. They were obtained by taking the total mileage of highways and interstates and dividing them by the area of each county. The original information for the variable was obtained for 2000 and 2006 from shapefiles taken from the Kansas Geospatial Community Data Access and Support Center (DASC). (Kansas Geospatial Community, 2000; 2006).

The bridge density variable represents the bridge density for each county. The bridge density variable was obtained by taking the total number of bridges per county and dividing that number by the area of each county. The information for the variable was extracted for 1992, 2001, and 2007 out of Kansas state bridges and Kansas non-state bridges shapefiles from DASC (Kansas Geospatial Community, 2007 A and B).

The percent of land used for sorghum, percent of land used for corn, percent of land used for hay, and percent of land used for wheat represent the total percentage of a county devoted to growing sorghum, corn, hay, and wheat. They were obtained by taking the total area of ground used for growing these crops and dividing it by the area of each county. The original data for the variable were obtained for 1992, 2002, and 2007 from the United States Department of Agriculture (USDA) Census of Agriculture National Agricultural Statistics Service (USDA, 1992; 2002; 2007).

The percent of land protected variable represents the percentage of land set aside in each county for protection from hunting. This land includes parks, wildlife sanctuaries, preserves, and other private and public lands. The percent of land protected variable was obtained by taking the total area of protected land and dividing it by the area of each county. The information for the variable was for 2008 and it was extracted from a shapefile downloaded from DASC (Kansas Geospatial Community, 2008).

The deer harvest density variable represents the deer harvest density for each county. The deer harvest density variable was obtained by taking the total number of deer killed per county and dividing that number by the area of each county. The information for the variable obtained for 2009 from the Kansas Department of Wildlife and Parks (KDWP, 2009).

The human population density variable represents the human population density for each county. The human population density variable was obtained by taking the total number of people per county and dividing that number by the area of each county. The information for the variable was obtained from the United States Census Bureau for the years 1992, 2001, and 2008 (US Census Bureau, 1990; 2000).

Research and Justification

This study will further the literature by providing an areal study of DVAs at the county scale for an entire state. Its methodology follows Iverson and Iverson (1999) and Farrell and Tappe (2007), by employing multivariate regression analysis to study DVA distributions in regard to possible causal factors.

I chose to conduct an areal study of Kansas because most of the available data were already recorded at the county scale in the state. While some of the data were available at a larger scale (in regard to maps), I chose the county scale, which matched that of the largest body of available data. Another reason I chose to conduct an areal study was that by examining an entire state, I might identify trends not apparent beyond the local scale. In addition to providing a broad view, this areal study of Kansas allows for the comparison of historic changes in DVA distributions and factors. This would be impossible to do for a site study.

This study further contributes to the literature because it examines a 17-year period, which is longer than any North American study found. Additionally, this study uses regression analysis for multiple years, something few studies have done, aside from Seiler (2004). This longer time span allows a temporal dimension to DVA research. While this study is not a typical time series analysis, analyzing three separate years provides snapshots of what factors are influencing DVAs within the overall time period. Furthermore, this study intends to benefit the State of Kansas by indentifying factors causing DVAs. It should also be valuable toward mitigating DVAs by indentifying at-risk counties. Additionally, the study is designed to be easily replicated.

CHAPTER III

METHODOLOGY

Time Period of Analysis

The purpose of this study is to identify factors responsible for DVA distributions in Kansas and how these have changed over time. The period under examination is 1992 to 2008, a period of high DVA rates. Specific years under examination include 1992, 2001, and 2008, since data are available for these years across the entire state. These years serve as cross-sectional cut-outs, giving key information about DVA factors and distributions for specific points in time for the overall period.

Scale of Study

This research is an areal study conducted at the county scale for the whole state. By conducting the analysis at the county level, the significance of the factors associated DVAs, such as human population density, will be identified. Research by Iverson and Iverson (1999), Seiler (2004), and Farrell and Tappe (2007) demonstrate the utility of an analysis at this scale.

Method of Analysis

The method of analysis will be multivariate regression models. Doing this identifies how specific independent variables influence the distribution of the dependent variable, DVA density. This method should explain variation in DVA distribution and associated factors based on similar research (Iverson and Iverson, 1999; Farrell and Tappe, 2007). The method of multivariate regression analysis I chose for my study was stepwise. Stepwise regression analysis works by taking a starting list of variables, which are then either kept in or removed from the regression model as it goes through a series of iterations. This is done in an attempt to obtain a final regression model with the greatest explanation power and smallest amount of error. Using multivariate regression analysis in this way will allow the two research questions to be answered. I considered as many potential DVA-affecting factors as possible.

Variables Examined

The dependent variable used was the DVA density per county, which was obtained by taking the number of DVAs occurring per county divided by the county area. The independent variables included in the models were highway density, interstate density, bridge density, percent of land used for sorghum, percent of land used for corn, percent of land used for hay, percent of land used for wheat, percent of land protected, deer harvest density, and human population density (Tables 2, 3, and 4). These variables have been identified to be significant factors in previous studies (Ross and McCullough, 1976;

Bashore, Tzilkowski, and Bellis, 1985; Finder, Roseberry, and Woolf, 1999; Seiler, 2004; Farrel and Tappe, 2007).

Table 2: 1992 Regression Variables

Dependent Variable – Kansas Department of Transportation	
DVAs	Deer Vehicle Accidents Densities: 1992
Independent Variables	
Land Cover	USDA: 1992
PctCorn	Percent of land used for corn
PctSorg	Percent of land used for sorghum
PctHay	Percent of land used for pasture or hay, non-crop producing ground
PctWheat	Percent of land used for wheat
Human Population	US Census Bureau : 1992
PopDen	Human Population Density
Bridges	Kansas Geospatial Community: 1992
Bridg	Bridge Densities

Sources: KDOT, 2010; Kansas Geospatial Community, 2007 A and B; US Census Bureau, 1990; USDA, 1992

Table 3: 2001 and 2008 Regression Variables

Dependent Variable – Kansas Department of Transportation	
DVAs	Deer Vehicle accidents Densities: 2001, 2008
Independent Variables	
Land Cover	USDA National Agricultural Statistics Service & Forest Service: 2002, 2007
PctCorn	Percent of land used for Corn
PctSorg	Percent of land used for Sorghum
PctHay	Percent of land used for pasture or hay, non-crop producing ground
PctWheat	Percent of land used for Wheat
Roads	Kansas Geospatial Community: 2000, 2006
Highway	Total Highway Mileage
Inter	Total Interstate Mileage
Human Population	US Census Bureau : 2001, 2008
PopDen	Human Population Density
Bridges	Kansas Geospatial Community: 2001, 2008
Bridg	Bridge Densities

Sources: KDOT, 2010; Kansas Geospatial Community, 2000; Kansas Geospatial Community, 2006; Kansas Geospatial Community, 2007 A and B; US Census Bureau, 2000; USDA, 2002; USDA, 2007

Table 4: 2008 Expanded Regression Variables

Dependent Variable – Kansas Department of Transportation	
DVAs	Deer Vehicle accidents Densities: 2008
Independent Variables	
Land Cover	USDA National Agricultural Statistics Service & Forest Service: 2008 DASC: 2008
PctCorn	Percent of land used for corn
PctSorg	Percent of land used for sorghum
PctHay	Percent of land used for pasture or hay, non-crop producing ground
PctWheat	Percent of land used for wheat
PctProt	Percent of land Protected
Roads	Kansas Geospatial Community: 2006
Highway	Total Highway Mileage
Inter	Total Interstate Mileage
Human Population	US Census Bureau : 2008
PopDen	Human Population Density
Bridges	Kansas Geospatial Community: 2007
Bridg	Bridge Densities
Deer Harvest #s	KDWP : 2009
DeerHarDens	Total Deer Harvest Density

Sources: KDOT, 2010; KDWP, 2009; Kansas Geospatial Community, 2006; Kansas Geospatial Community, 2007 A and B; Kansas Geospatial Community, 2008; US Census Bureau, 2000; USDA, 2007

I created my models using different combinations of a starting pool of variables. I chose the model with the highest R^2 as the final model because it had the most explanation power. Another reason I chose this method was because several of the stepwise models retained variables even when there were high levels of multicollinearity. Multicollinearity exists when variables explain the same phenomena. Mutlicollinearity can be detected when the V.I.F. (Variance Inflation Factor) numbers are greater than 5. High levels of multicollinearity reduces the accuracy of a regression model, so for certain years several of the variables had to be forcibly removed to keep multicollinearity within acceptable levels.

For all the models I attempted to have as similar starting list of variables as possible to facilitate in the comparison between the models. There were, however, several potentially important variables, percent of land protected and deer harvest densities, which only had data available for 2008. To include these variables in my study I ran a separate regression model, the 2008 expanded regression model. Including these variables in a separate model allowed me to maintain consistency between the starting variables in the regular 2008 and other years' models.

One further problem involved data for roads. Continual updating of roads files limited historic roads data to the year 2000 rather than 1992. Since eight years of change would potentially generate error, I excluded the highway density and interstate density variables for 1992. I included the following description of the steps used for my examination of 2001 to help clarify my methodology and decision making processes.

I incorporated all the variables in the first regression model and found bridge density, human population density, highway density, and percent of land used for hay to be influential with a combined R^2 value of 0.773. For the next model, I removed the percent of land used for sorghum and percent of land used for corn variables. I did this because they were excluded by the original stepwise model and they were also missing information for three counties. This meant that only 102 of the 105 Kansas counties were included as observations in the model. By removing these two variables, I wanted to determine if only having variables with a complete dataset for Kansas would affect the accuracy of the model. Their removal raised the R^2 value to 0.872.

While I felt this was a significant improvement, interstate density inclusion in the model caused the V.I.F. values to rise above the cut-off of 5. I determined the cause of this V.I.F. increase was because interstate density correlated highly with several other variables. The high V.I.F.s made the results questionable. I corrected this in the final regression model by forcibly removing the interstate density variable. I then had bridge density, human population density, highway density, percent of land used for hay, and percent of land used for wheat as variables. All of these variables made it into the final stepwise model except for percent of land used for wheat which was excluded by the model.

I executed multiple other regression models, but the model using bridge density, human population density, highway density, and percent of land used for hay ended up having the best explanation power with a R^2 value of 0.867. I used this same process of having all the variables in my initial model, then adding and removing variables in subsequent models based off completeness of the data and V.I.F values for each of the years in my study. By performing my analysis in this method I was able to maintain as much uniformity as possible between the models. This allowed me to compare the year to year changes of influential variables between the models and the models overall level of explanation of DVA distributions. The results of this method of examination lead to several findings discussed in the following section.

CHAPTER IV

FINDINGS

Model Findings

For 1992, the best stepwise model had human population density, percent of land used for wheat, bridge density, percent of land used for hay, percent of land used for corn, and percent of land used for sorghum as the starting variables. Percent of land used for corn and percent of land used for sorghum did not make it into the final stepwise model. Based on the ANOVA table, the model was significant with an F statistic of 164.689 and significance value of 0.000. Any significance value less than 0.05 is considered significant at the 95th percentile, the normal cut-off used in geographic analysis. Human population density was the first variable included; it had an R^2 value of 0.768. This means that human population density accounted for almost 77 percent of the variation in DVAs. The next variable included was percent of land used for hay which added 0.074 to the R^2 value bringing it to 0.842.

Bridge density was the third variable included which raised the R^2 value by 0.01 to 0.852. Percent of land used for wheat was the final variable included, adding 0.019 to the R^2 which brought the final value to 0.872. This means that these four variables accounted for 87 percent of the variation in DVAs in 1992. The formal regression equation for the model is represented below.

DVA= 0.025 + 0.580(Human population density) + 0.097(Percent of land used for hay) + 0.312(Bridge density) - 0.165(Percent of land used for wheat)

Looking at the sign for each of the coefficients reveals which type of correlation, whether positive or negative, the independent variable has with regard to the dependent variable (Table 5). Based on the beta coefficients, it is apparent that human population density, percent of land used for hay, and bridge density are all positively correlated with DVAs. Meanwhile, percent of land used for wheat is negatively correlated with DVAs. This means that with an increase in human population density, percent of land used for hay, or bridge density, an increase in DVAs would be expected. For percent of land used for wheat, in contrast, a decrease in DVAs would be expected.

Additionally, human population density, bridge density, and percent of land used for wheat were all found to be individually significant beyond the normal 0.05 cutoff, as each had a significance value of 0.000. For the individual significance values, the closer the values are to 0.000, the higher the significance and less chance there could be errors. Percent of land used for hay, however, was only found to be significant at the 0.1 level as it had a significance value of

0.067. While this is not a terrible significance value (there is less than a 10% probability that there is no relationship between DVAs and percent of land used for hay) it is higher than the normal 0.05 cutoff. This casts some doubt on the relationship between DVAs and percent of land used for hay. Nevertheless, there is a 90% chance of a relationship, so it should not be entirely ruled out.

Table 5: 1992 Regression Results

1992 Best Model	Included Variables	R Square Change	Standardized Beta Coefficient	Significance Value
1	PopDen	0.768	0.580	0.000
2	PctHay	0.074	0.097	0.067
3	BridDen	0.010	0.312	0.000
4	PctWheat	0.019	-0.165	0.000

For 2001, a stepwise model including bridge density, human population density, highway density, percent of land used for hay, and percent of land used for wheat (which was excluded by the model) gave the best R^2 value. The ANOVA table again revealed the 2001 model was also significant with an F statistic of 162.683 and a significance value of 0.000. Bridge density was the first variable included. It resulted in R^2 value of 0.727. Human population density was the next variable to make it into the model, raising the R^2 value by 0.066 to 0.793. Highway density was the third variable, which brought the R^2 value up by 0.054 to 0.847. Percent of land used for hay was the last variable included, which increased the final R^2 value by 0.020 to 0.867. The formal regression equation for the 2001 model was:

DVA = -0.103 + 0.179(Bridge density) + 0.551(Human population density) + 0.268(Highway density) + 0.177(Percent of land used for hay)

All the variables included in the 2001 stepwise model had positive standardized beta coefficients (Table 6), meaning each had a positive correlation with DVAs. As such, an increase in any of these variables would lead to an increase in DVAs. For 2001, all the individual variables had significance values less than the 0.05 cutoff. This included bridge density, human population density, highway density, and percent of land used for hay. Of the four variables, the only one that did not have a 0.000 significance value was bridge density, 0.028, but it was still significant in its relationship to DVAs.

Table 6: 2001 Regression Results

2001 Best Model	Included Variables	R Square Change	Standardized Beta Coefficient	Significance Value
1	BridDen	0.727	0.179	0.028
2	PopDen	0.066	0.551	0.000
3	HighDen	0.054	0.268	0.000
4	PctHay	0.020	0.177	0.000

The best regression model for 2008 had bridge density, human population density, highway density, percent of land used for hay, and interstate density (which was excluded by the model) as variables. The 2008 regression model was significant with an F statistic of 266.387 and significance value of 0.000. Once again, bridge density was the first variable included in the regression model. It brought the R^2 value to 0.815. Human population density was next, raising the R^2 value by 0.053 to 0.868. Highway density was third, which raised the R^2 value by 0.036 to 0.904. Finally, percent of land used for hay was the last variable included which added 0.010 and brought the final R^2 value to 0.914. The formal regression equation for the 2008 model was:

DVA= -0.042 + 0.315(Bridge density) + 0.482(Human population density) + 0.232(Highway density) + 0.121(Percent of land used for hay)

The 2008 stepwise model included variables all with positive standardized beta coefficients indicative of positive correlation with DVAs (Table 7). Additionally, each variable was significant, all with values below the 0.05 cutoff. Of the four variables, bridge density, human population density, and highway density each had significance values of 0.000, while percent of land used for hay returned a significance value of 0.001.

Table 7: 2008 Regression Results

2008 Best Model	Included Variables	R Square Change	Standardized Beta Coefficient	Significance Value
1	BridDen	0.815	0.315	0.000
2	PopDen	0.053	0.482	0.000
3	HighDen	0.036	0.232	0.000
4	PctHay	0.010	0.121	0.001

The best expanded regression model for 2008 had bridge density, human population density, deer harvest density, highway density, percent of land used for hay, percent of land protected, and interstate density as variables. Percent of land used for hay, percent of land protected, and interstate density did not make it into the final stepwise model. The expanded 2008 model was also significant with an F statistic of 316.250 and significance value of 0.000.

Bridge density was the first variable included in the expanded regression model bringing the R^2 value to 0.813. Human population density was added second, raising the R^2 value by 0.053 to 0.865. Next, deer harvest density was included in the model, increasing the R^2 value by 0.036 to 0.904. Highway density was the last variable added, adding 0.023 to R^2 which brought the final R^2 value to 0.927. The formal regression equation for the expanded 2008 model varied from the original 2008 equation and is listed below.

DVA= -0.049 + 0.285(Bridge density) + 0.468(Human population density) + 0.189(Deer harvest density) + 0.209(Highway density)

Like 2008, the expanded 2008 regression model only had positive correlations between the identified variables and DVAs, according to standardized beta coefficients (Table 8). Each variable was also significant in its respective relationship to DVAs, as each had a significance value of 0.000.

Table 8: 2008 Expanded Regression Results

2008 Extend Best Model	Included Variables	R Square Change	Standardized Beta Coefficient	Significance Value
1	BridDen	0.813	0.285	0.000
2	PopDen	0.053	0.468	0.000
3	DeerHarDen	0.036	0.189	0.000
4	HighDen	0.023	0.209	0.000

Discussion of the Models

Of the four regression models, at this scale of analysis, the expanded 2008 model provides the best explanation of the relationship between the variables and the distribution of DVAs, with an R^2 value of 0.927. The next best model was the regular 2008 regression model, which had an R^2 value of 0.914. This was followed by the 1992 model, which had an R^2 value of 0.872. The 2001 regression model was last, with an R^2 value at 0.867. Overall, more than 86 percent of the variation in the relationship between the variables and DVA distributions can be explained by each of the four models.

Overall, there was not much variation in the variables found influential by the stepwise models. Bridge density, human population density, and percent of land used for hay were found to be influential in 1992, 2001, and 2008. Human population density, bridge density, and highway density were found to be influential in 2001, 2008, and the expanded 2008 model.

The main difference between the final regression models was that percent of land used for wheat was found to be influential in 1992, but not in the other years. This may be because the 1992 regression model did not include roads variables, which included highway density and interstate density. If roads variables had been included, then the percent of land used for wheat might have been excluded. Additionally, the expanded 2008 regression model was the only model not to include the percent of land used for hay. Instead, it found that deer harvest density, which was only included for this separate model, was influential.

Human population density and bridge density were found to be influential in all the regression models.

The amount of explanation power each variable added to the regression models was fairly consistent in each model, except 1992. In 1992, human population density explained the largest amount of variance, 76.8%, but its exploratory power was much lower in the other years' models. This was because bridge density emerged with the greatest explanatory power. Human population density explained 6.6% in 2001, 5.3% in 2008, and 5.3% in the expanded 2008 regression model. For 1992, bridge density only explained 1% of the variation in DVAs, while in 2001 it jumped to 72.7%, 81.5% in 2008, and 81.3% in the expanded 2008 model.

The other variables included in the final regression models had significantly less variation throughout the years. Highway density explained 5.4% in 2001, 3.6% in 2008 and 2.3% in the expanded 2008 model. Percent of land used for hay explained 7.4% in 1992, 2.0% in 2001, 1.0% in 2008, and was not included in the expanded 2008 model. Deer harvest density explained 3.6% in the expanded 2008 model and percent of land used for wheat accounted for 1.9% of the variation of DVAs in 1992. Because of the high explanation power, low level of variance among variables included, and their levels of influence; it is likely that these regression models are accurately representing the factors that are influencing DVA distributions in Kansas.

Discussion of Influential Variables

The inclusion of the bridge density variable in every regression model makes it stand out as a key explanatory variable. This corresponds with Danielson, Hubbard, and Schmitz's (2000) observations in Iowa that bridges were often sites of higher DVA occurrence. There are several reasons why bridges are associated with higher DVA rates. Bridges mark the intersections of automobile travel (roads) and the riparian routes deer travel (stream valleys). Because both people and deer are intersecting at bridges, this may explain the greater concentrations of DVAs.

Another possible effect the bridges could have is that the slope of the road near bridges is often higher. This could limit the visibility of motorists. Bellis and Graves (1971) found that similar factors including changes in slope, presence of gullies, and vegetation were associated with higher DVA concentrations in Pennsylvania.

The inclusion of bridge density in the regression model makes further sense after a visual inspection of the maps of DVA densities and Bridge Densities: 1992 (Figures 2 and 3), 2001 (4 and 5), 2008 (6 and 7). Counties with low DVA densities appeared to have low bridge densities while counties with high DVA densities were often associated with high bridge densities.

Figure 2: 1992 Kansas Bridge Densities Map

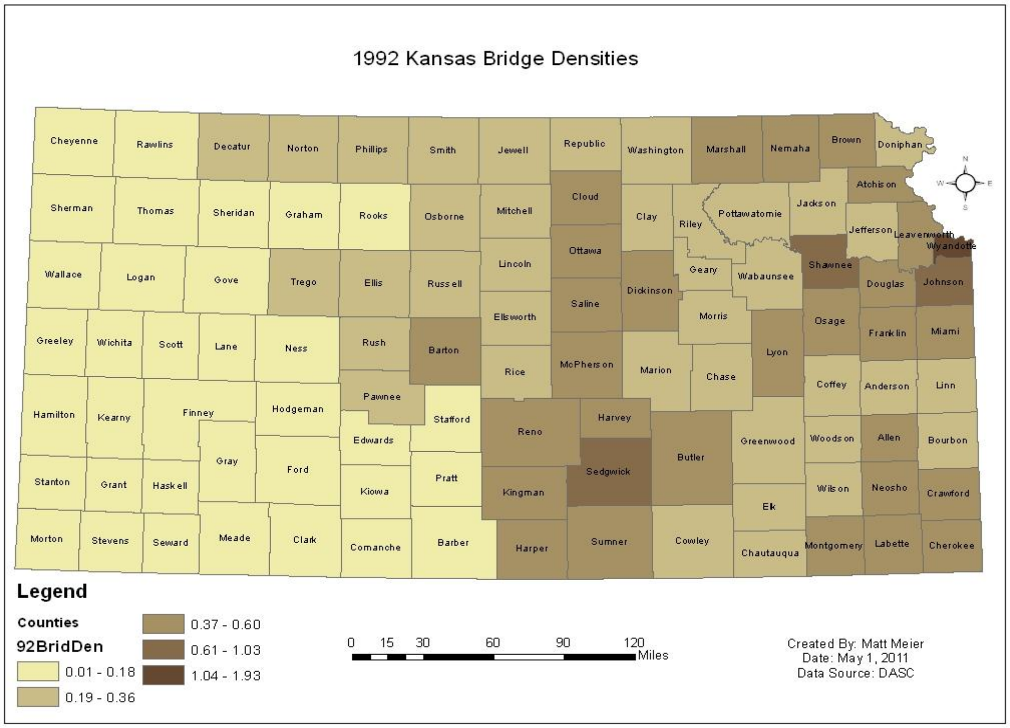


Figure 3: 1992 Kansas DVA Densities Map

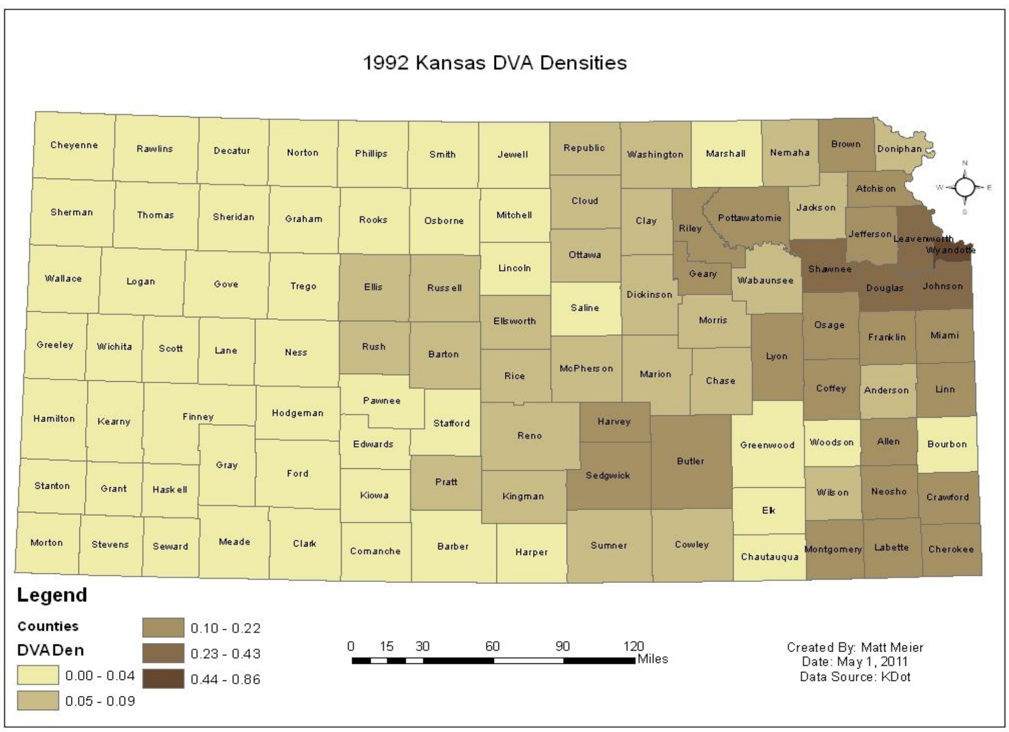


Figure 4: 2001 Bridge Densities Map

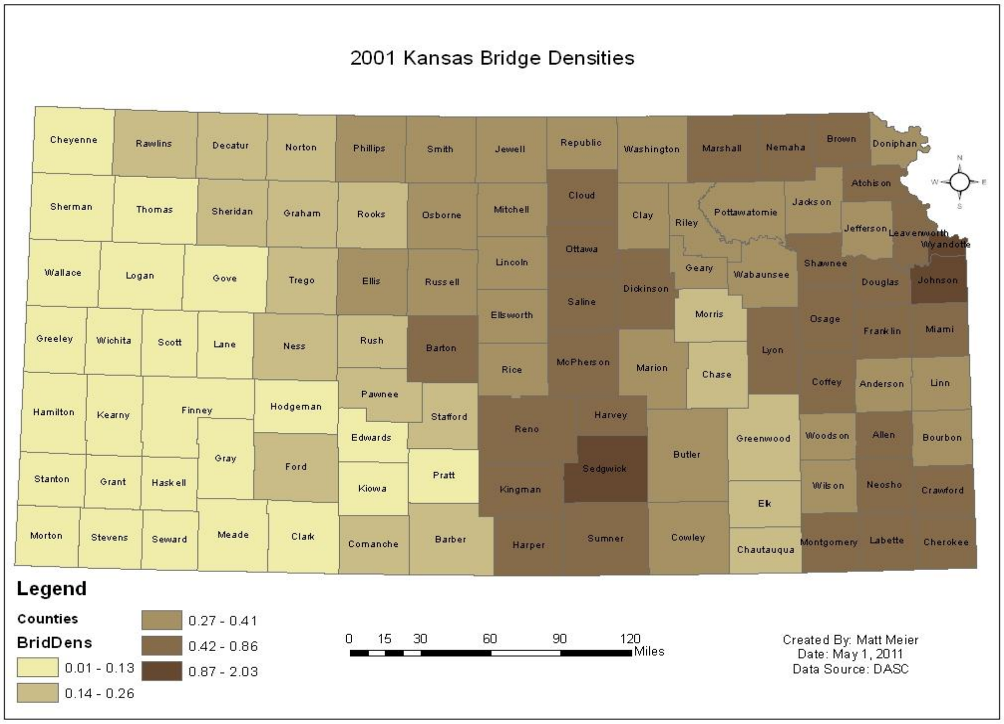


Figure 5: 2001 Kansas DVA Densities Map

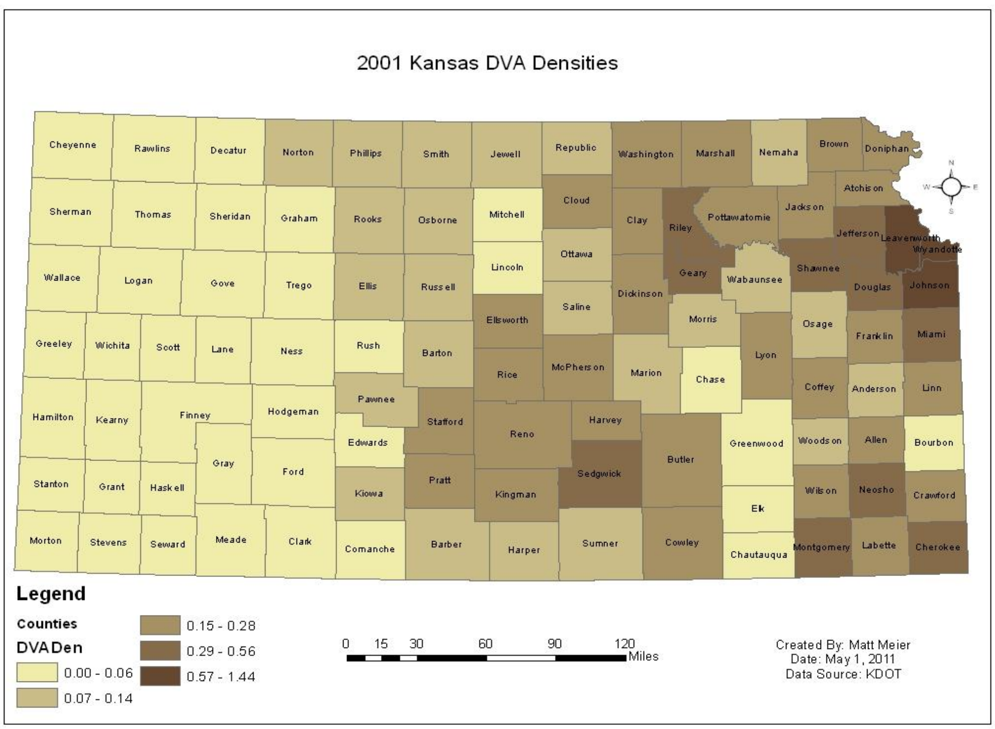


Figure 6: 2008 Kansas Bridge Densities Map

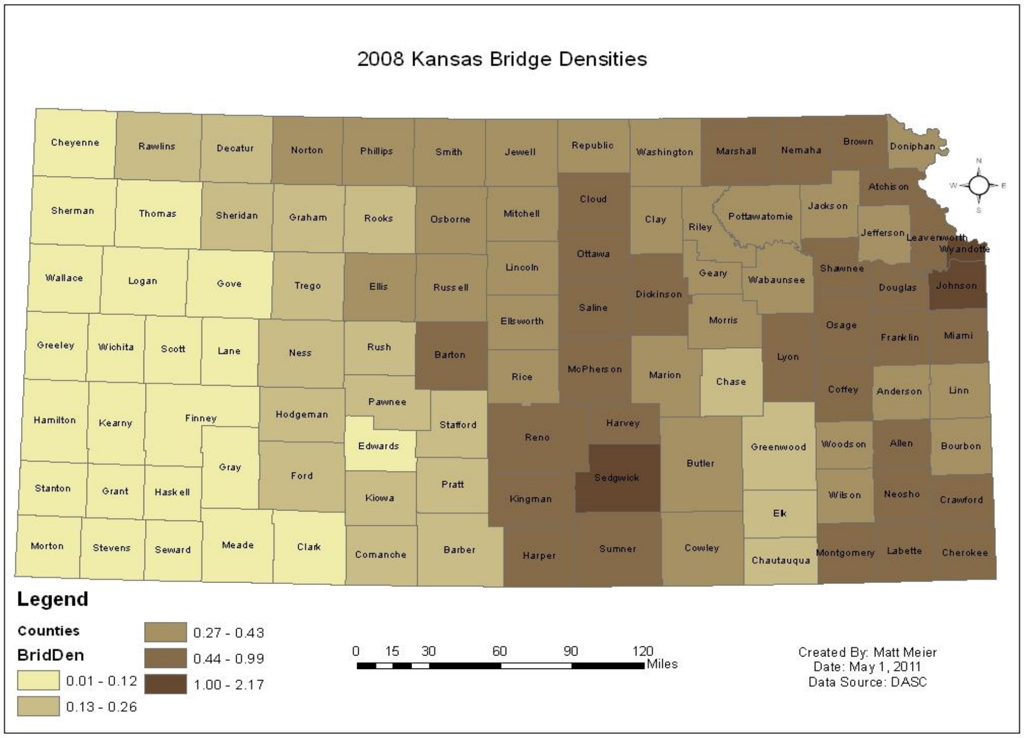
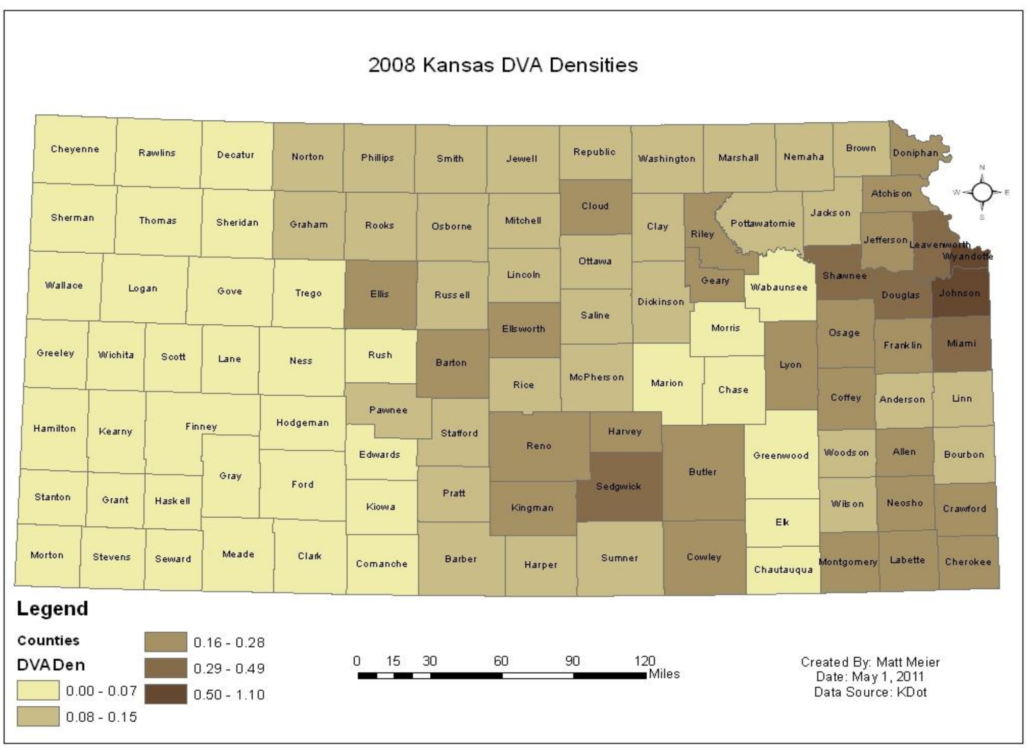


Figure 7: 2008 Kansas DVA Densities Map



Human population density was another variable found to be influential in each regression model. Iverson and Iverson (1999) came to a similar conclusion in their study of DVAs in Ohio. The positive correlation of human population density and DVA densities in all models indicates that with an increase in human population density, there is an expected increase in DVA densities. A possible explanation for this would be that higher populations equate to more vehicles and increased likelihood of DVAs.

Another possible reason is that higher human population densities are associated with the counties containing larger cities in Kansas. Motorists traveling through an urban environment may be less likely to be looking for deer as they could mistakenly believe that deer do not live in cities. This could lead to more lax driving habits and increase the likelihood they would not see an approaching deer and have a DVA.

Additionally, areas with high human population densities could serve as possible deer refuges because hunting within city limits is general illegal. Deer tend to overpopulate in areas where hunting is prohibited, such as cities and state parks. The presence of forested parks, golf courses, or overgrown empty lots within cities could be used as habitat for the deer. In Shawnee Mission Park, for example, a park of 3.5 square miles in Kansas City, deer density was estimated at 195-208 per square mile, which necessitated a culling program (KDWP, 2010). This phenomenon is more than likely occurring in multiple other counties with large human populations and cities. Examining the maps of human population densities compared to DVAs suggests that the counties with the highest human population densities have the highest DVA densities. Counties with low human population densities, however, tended to have low DVA densities: 1992 (Figures 8 and 9), 2001 (10 and 11), 2008 (12 and 13).

Figure 8: 1992 Kansas Human Population Densities Map

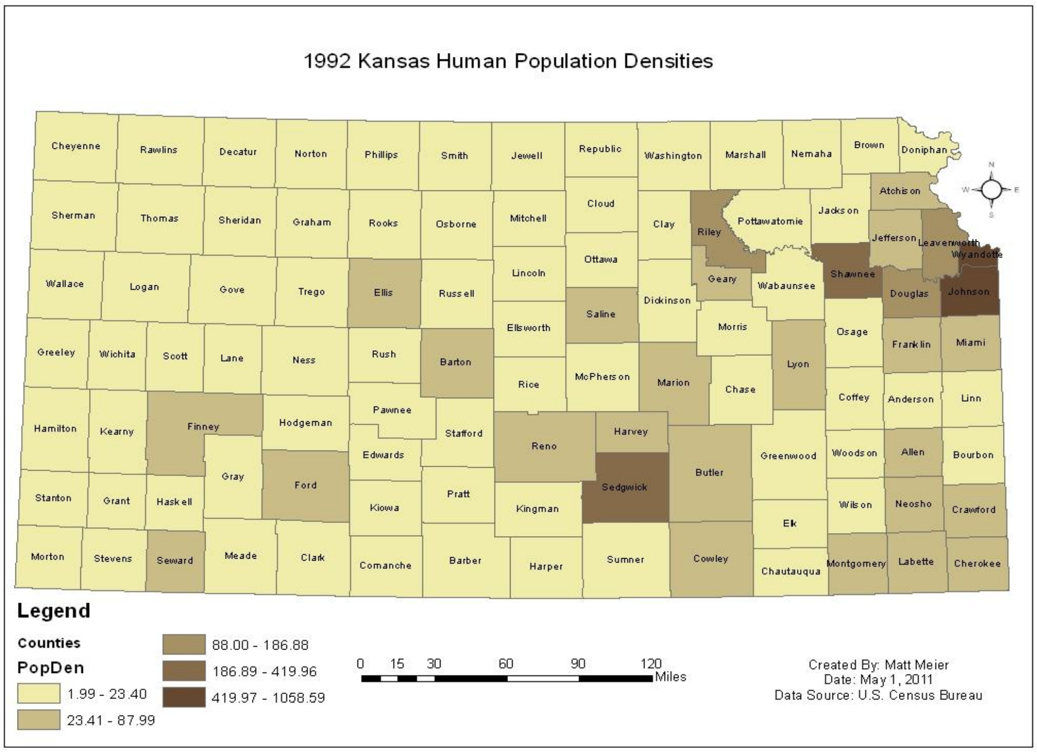


Figure 9: 1992 Kansas DVA Densities Map

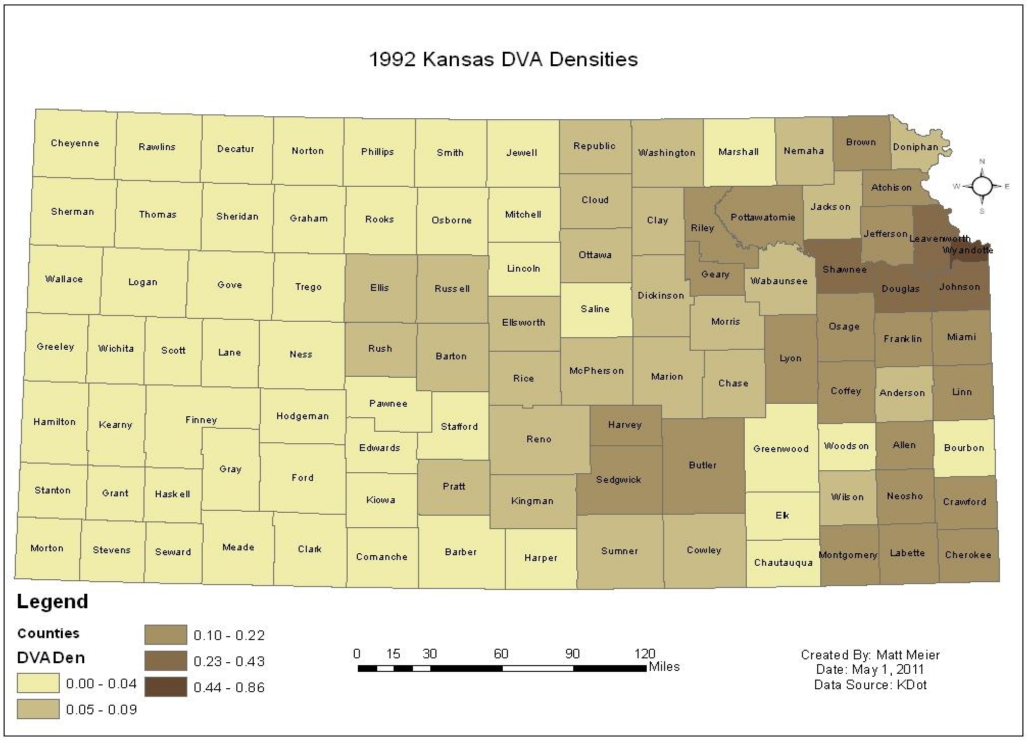


Figure 10: 2001 Kansas Human Population Densities Map

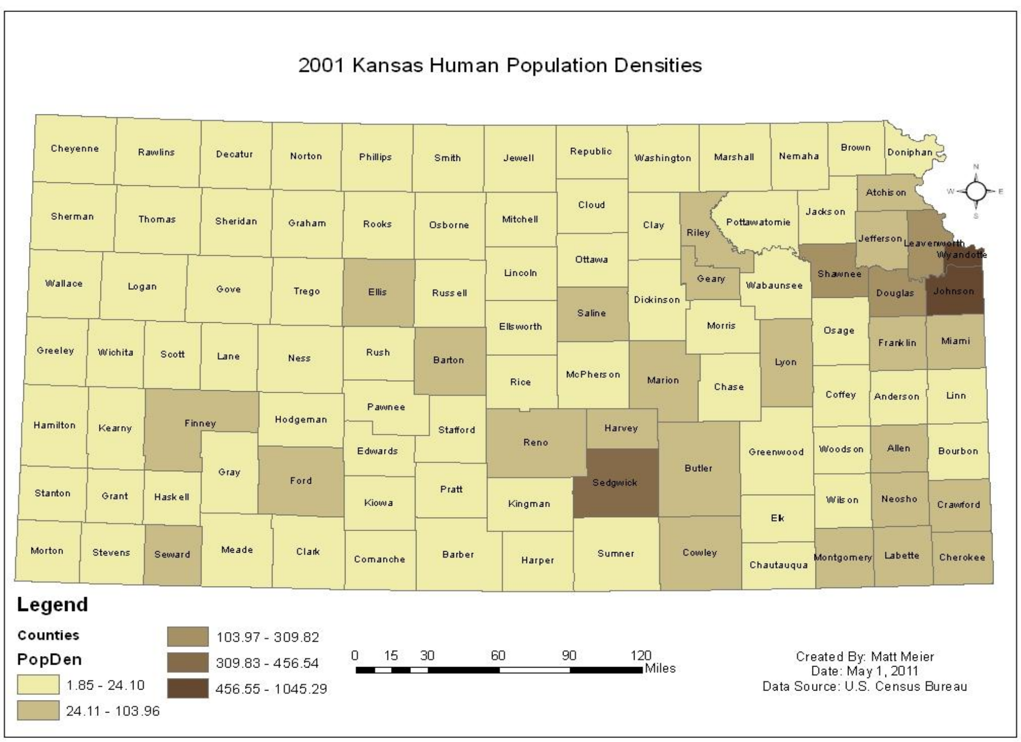


Figure 11: 2001 Kansas DVA Densities Map

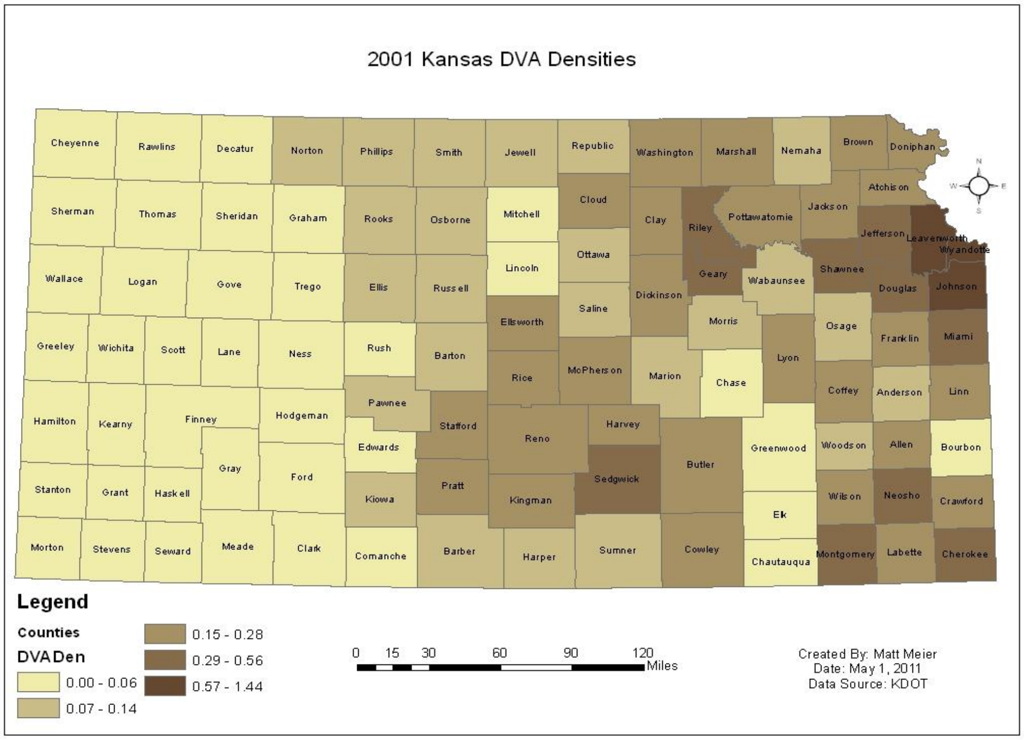


Figure 12: 2008 Kansas Human Population Densities Map

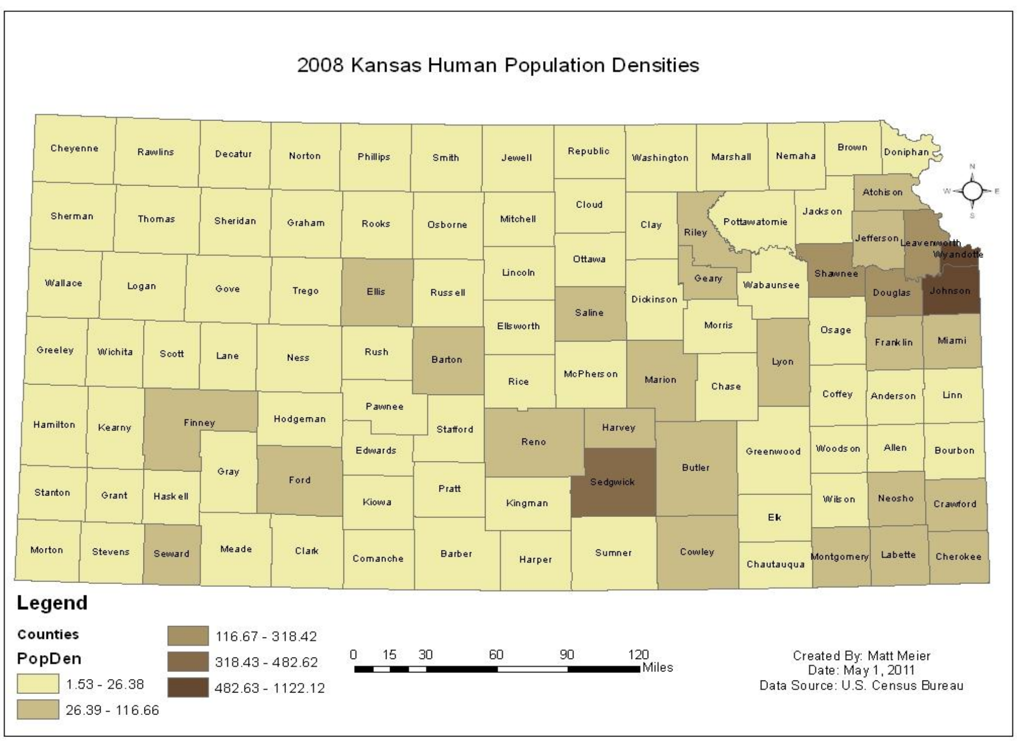
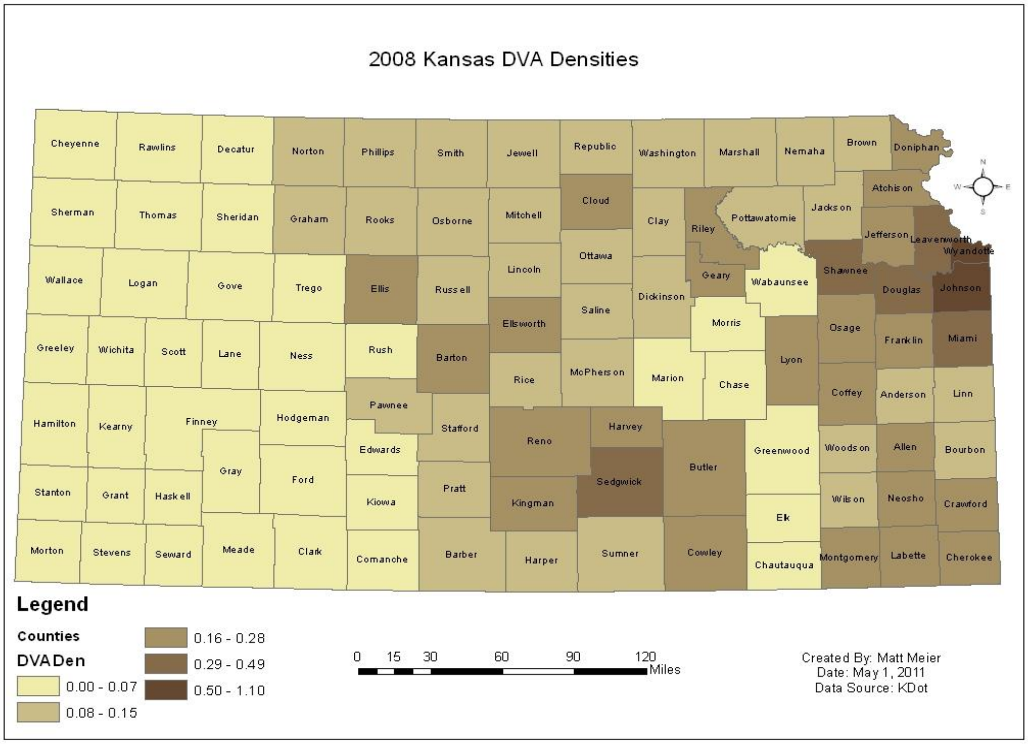


Figure 13: 2008 Kansas DVA Densities Map



The inclusion of highway density in the 2001, 2008, and (extended) 2008 models demonstrates the importance of this variable's relationship to DVAs. As would be expected, my results were similar to Iverson and Iverson (1999), and Sieler (2004) who found that highway densities correlated with DVA densities. Obviously the presence of more highways within a county would allow more vehicles to travel through it and in more areas, which would likely increase the chance of a DVAs occurring.

While highway density was important, it also should be looked at in comparison with the other roads variable, interstate density. The fact that highway density was included in many of the best regression models while interstate density was not is important. This could signify that the architecture of the interstates makes them less susceptible to deer. One possible reason for this is that interstates have four lanes while state and federal highways generally only have two lanes. This could be important because the extra lane may allow motorists to have a greater flexibility to avoid deer and also possibly see it sooner. Since much of the interstate mileage located in Kansas is separated, with a dividing area located between the either east and west or north and south lanes, the clear areas drivers have to view deer would also be greater because of this. A final factor may be because there is a greater presence of state and federal highways in Kansas than interstates. Figures 14 and 15 represent the highway density distributions within Kansas.

Figure 14: 2001 Kansas Highway Densities Map

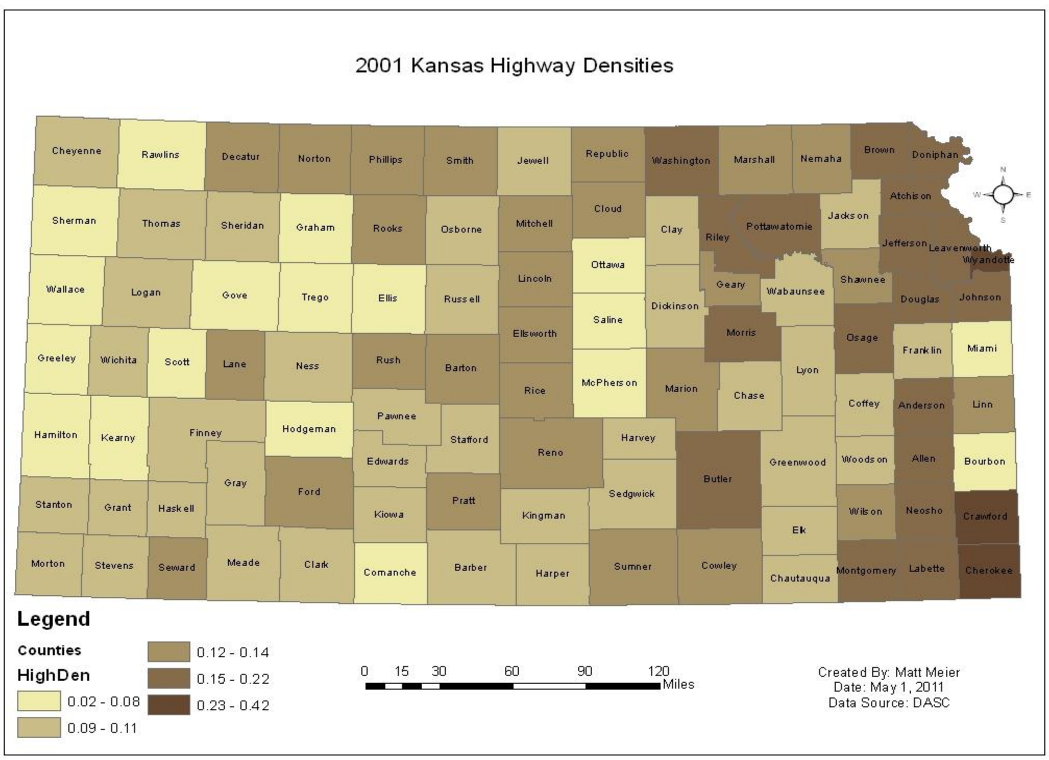
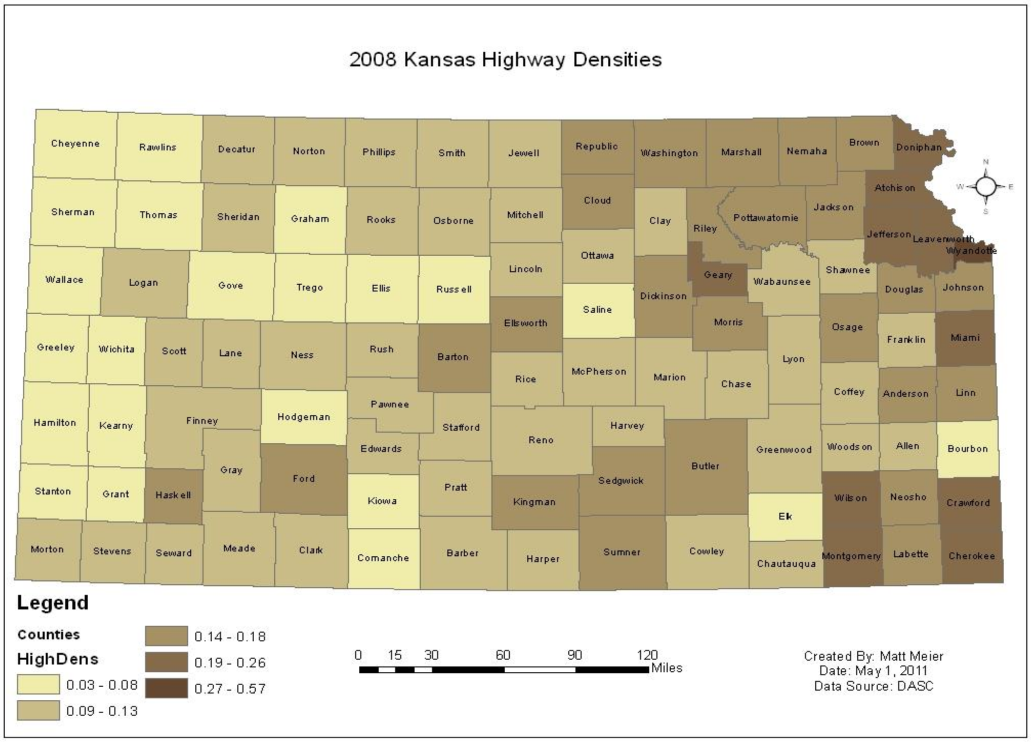


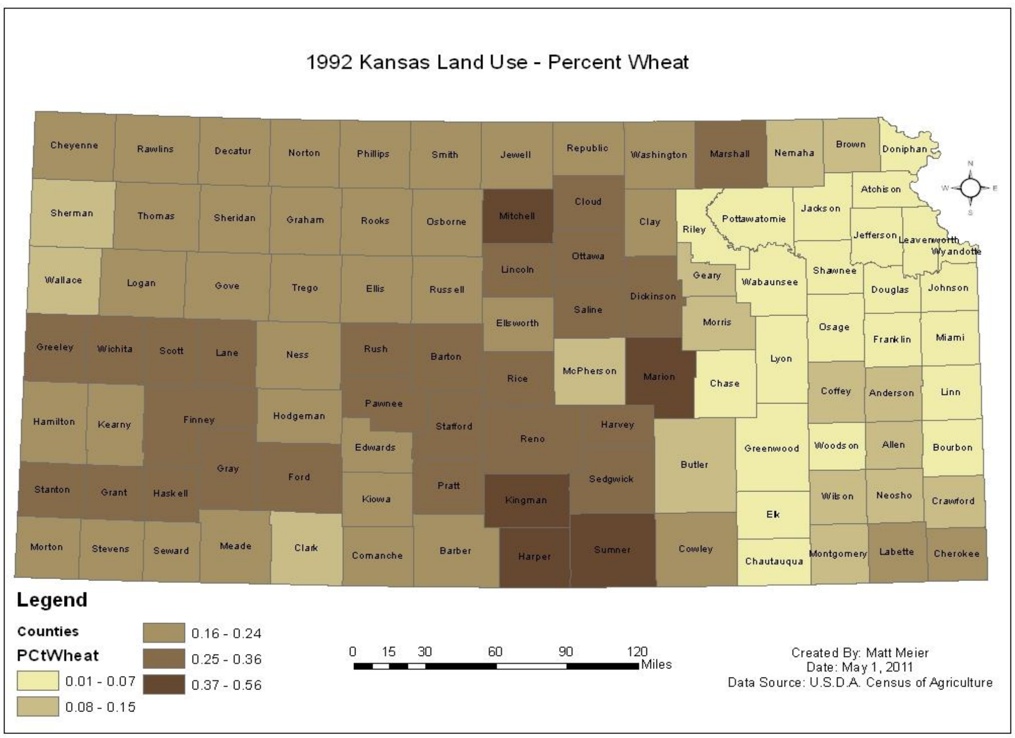
Figure 15: 2008 Kansas Highway Densities Map



Percent of land used for wheat was an additional variable included in a final regression models. However, it was only found influential in 1992. Moreover, it was the only variable included in the regression models that had a negative correlation to DVAs. This could possibly be explained by the life cycle of wheat and farming practices associated with it. While wheat can be grown on a variety of plot sizes; in Kansas it is typically grown in large fields, especially in western Kansas. Even though deer can be found feeding on wheat, it provides little overall cover and habitat for them (Bellis et al., 1975). This could be the case throughout wheat's life cycle because even in maturity, a grown deer will still stand out significantly in a field, so it is of limited use for deer as cover and allows motorists to see them easier.

By summer wheat is harvested so there is even less cover available for deer. Because many western and central counties in Kansas are associated with large amount of wheat production (Figure 16), there may be less suitable habitat for deer there and possibly smaller deer populations as a result. Hygnstrom and Vercauteren's (1998) findings that corn harvests in Nebraska affected the home ranges of deer adds credence to this possible explanation.

Figure 16: 1992 Kansas Land Use – Percent Wheat Map



Even though it did make it into the model, the overall Pearson's correlation value between percent of land used for wheat and DVAs was low, -0.385, and it only added only an additional 2% to the R^2 value. This could signify that this variable may not have direct effect on DVAs, but instead is influential to DVAs through the distribution of deer populations.

The percent of land used for hay was influential in all models except for the extended 2008 model. Additionally, percent of land used for hay had a positive correlation with DVAs in all the models. It should be noted that the percent of land used for hay variable was the only land use variable found influential in multiple models. Like percent of land used for wheat, percent of land used for hay likely has little direct impact on DVAs and is instead influencing DVAs through deer distributions and densities.

A possible explanation for why the percent of land used for hay was influential and included in the models may be that the hay serves as a food source for deer. Since hay grows rapidly, allowing multiple harvests per year, this would serve as a constant food source for deer (Rayburn, 2006). This could cause deer to concentrate in areas around hay fields leading to higher densities, especially if there was other habitat nearby suitable for bedding. Figures 17, 18, 19 represent the present of land used for hay distributions in Kansas. The maps reveal that counties with the highest percentages of land used for hay are primarily located in the eastern and central portions of Kansas, where the highest DVA densities were also found.

Figure 17: 1992 Kansas Land Use – Percent Hay Map

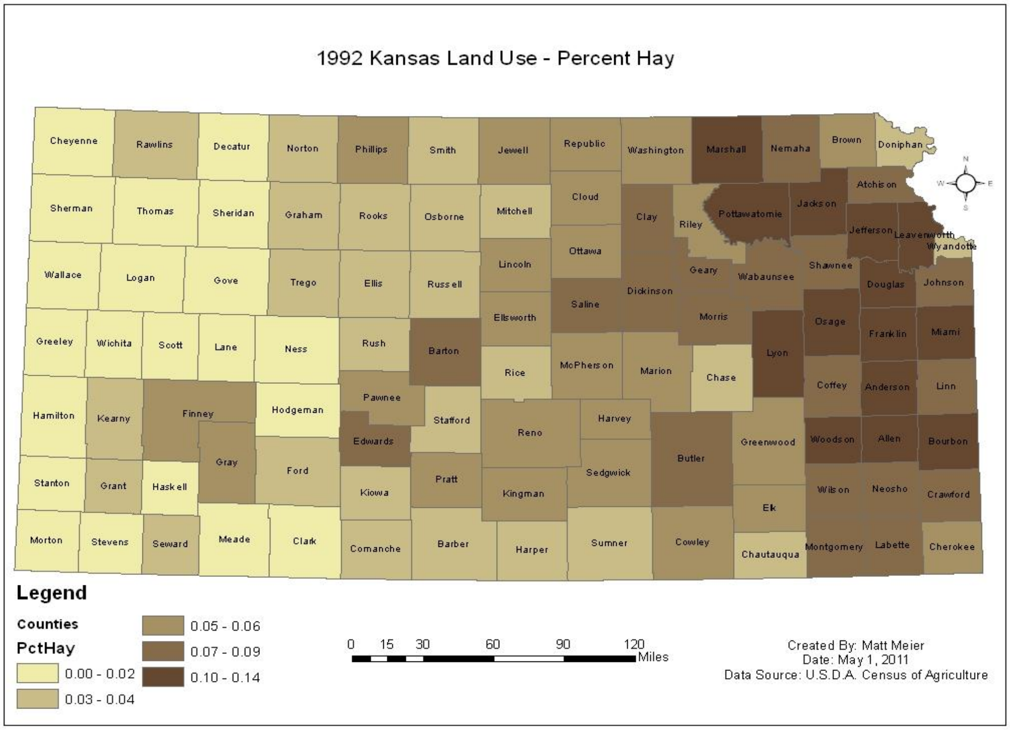


Figure 18: 2001 Kansas Land Use – Percent Hay Map

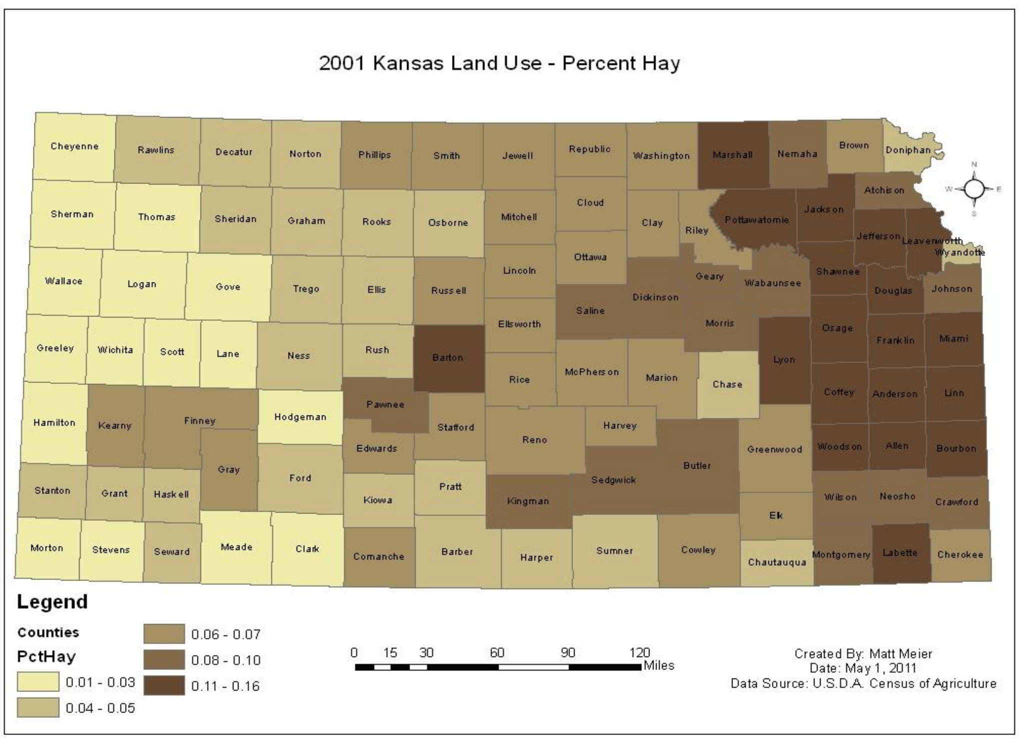
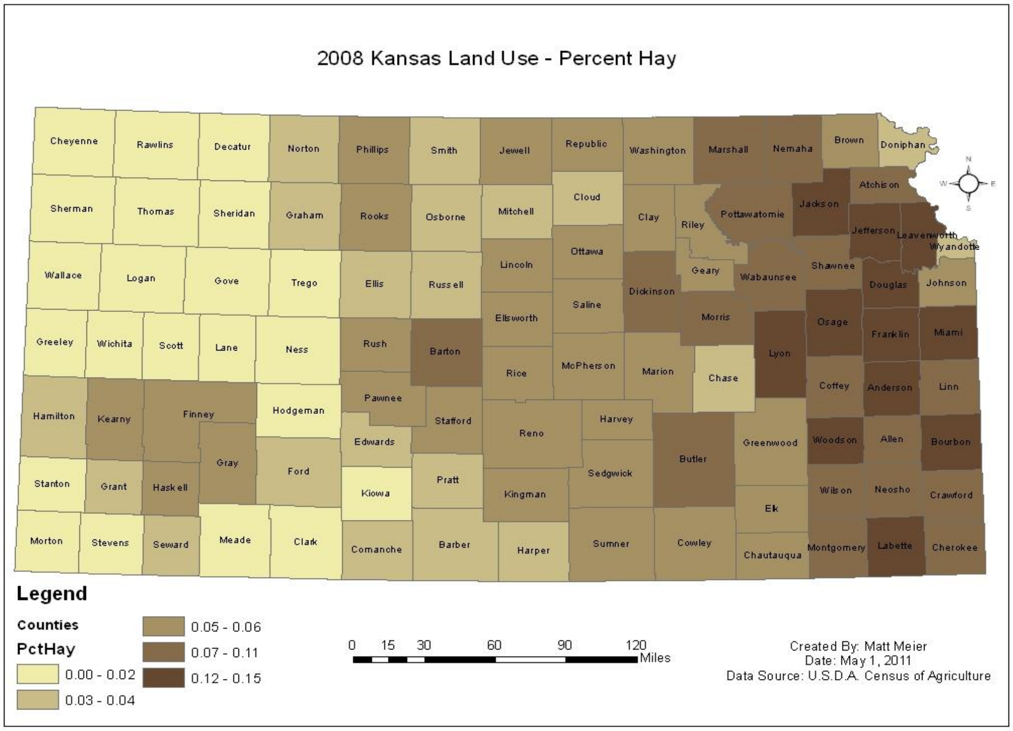


Figure 19: 2008 Land Use – Percent Hay Map



Deer harvest density was included in the final 2008 extended model. This result corresponds with the conclusion from Delger et al.'s (2008), however, it stands in contrast to the results of Iverson and Iverson (1999), who found deer harvest densities did not correlate with DVAs.

The reason deer harvest density was influential may be because it correlates with deer densities; however, the validity of this has yet to be proven and has been contested. The argument behind why deer harvest densities represent deer densities is that larger harvest numbers would require larger deer populations. Smaller harvest numbers would then signify smaller deer populations as there would be less deer to kill. Counter arguments; however, are that the success rate of hunters may be greater in counties with higher deer harvest densities or that fewer hunters are present in counties with lower deer harvest densities. The conclusion from this view is that the deer harvest densities have nothing to do with deer densities.

If the arguments are ignored and the assumption is made that deer harvest densities represents deer densities, then the results make sense. This is because in counties where there are larger deer populations, it would be expected that there would be higher DVA densities and in counties with smaller deer populations there would be lower DVA densities. The primary reason behind this is because if there are more deer within a county, then there are more deer for motorists to possibly hit. A visual comparison of the 2008 DVA density map to the 2009 deer harvest density map (Figures 20 and 21) demonstrates this trend. Examining the maps reveals that many western counties in Kansas have lower DVA densities and deer harvest densities while multiple eastern Kansas counties have higher DVA densities and higher deer harvest densities.

Figure 20: 2009 Kansas Deer Harvest Densities Map

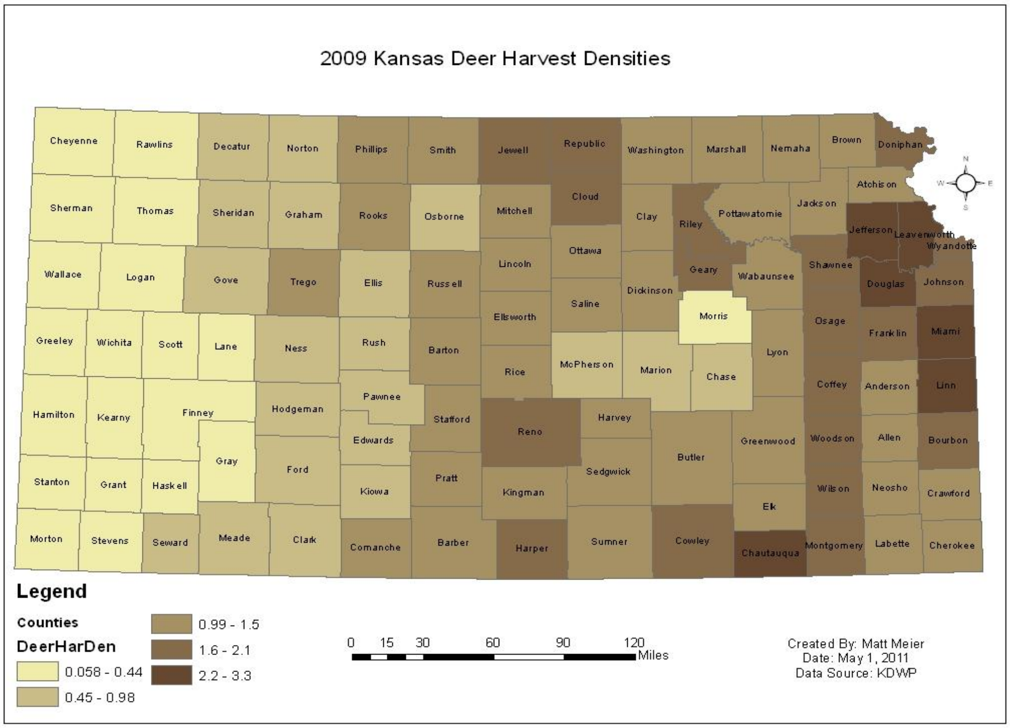
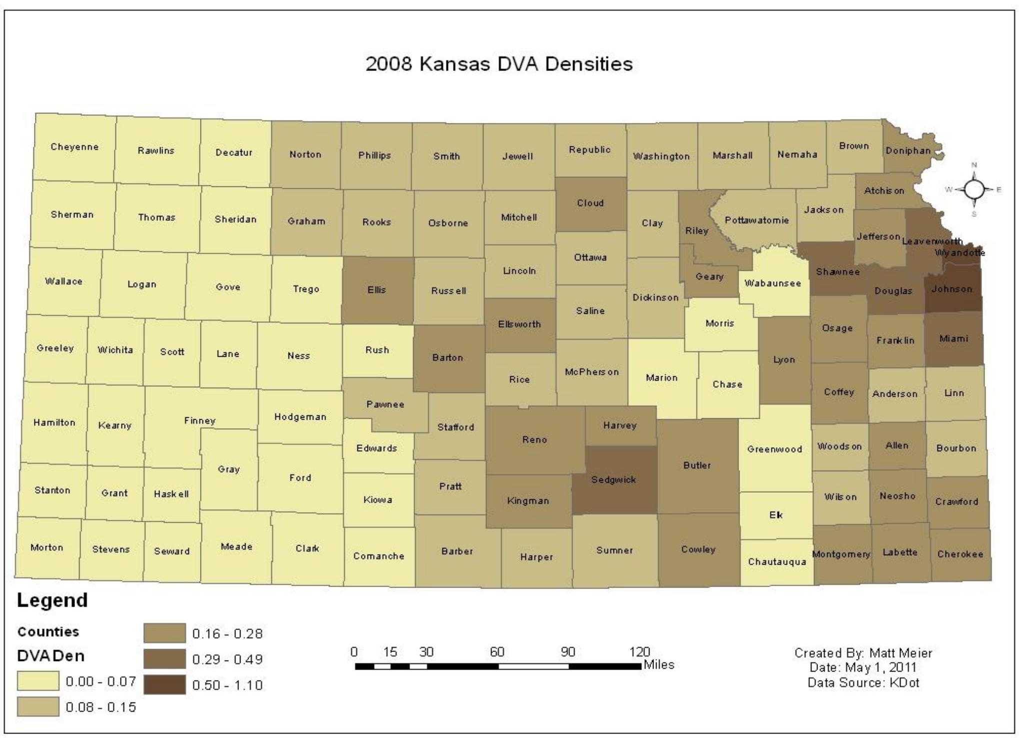


Figure 21: 2008 Kansas DVA Densities Map



By identifying the variables responsible for influencing the distribution of DVAs in Kansas, possible mitigation techniques can now be identified to deal with these specific factors. Additionally, identifying why bridge density, human population density, highway density, percent of land used for wheat, percent of land used for hay, and deer harvest density may have been influential helps to further refine the steps that can be taken to reduce DVAs. Furthermore, due to the consistency of results from the models, it's likely these variables are some of the true causes of DVAs. This increases the likelihood that mitigation techniques targeted at these factors will help reduce DVAs. Despite the regression models high levels of explanatory power, some steps can be taken in the future to increase their accuracy. This is discussed in the following chapter.

CHAPTER V

CONCLUSION

What Findings Mean for Kansas

What can be gained from these results is that factors that are human and infrastructure related (human population density, bridge density, and highway density) have been the most influential in affecting DVA distributions for multiple years. Additionally, all these variables had positive relationships, meaning that with an increase in human population and infrastructure there was a corresponding increase in DVAs for the models. The inclusion of several of the land use variables in multiple regression models signifies that land use can be important in determining the distribution of DVAs. However, the land use variables were not as important as the variables dealing with infrastructure and human population, nor as consistent (i.e. wheat's negative sign).

Based on these findings, likely trends would be continued higher DVA rates in the eastern and central portions of Kansas, as the human population density and infrastructure supporting it continues to grow in many counties there. The western portion of Kansas will likely continue to have lower DVA rates, which may drop further as many counties within western Kansas are seeing decreased human population densities (U.S. Census Bureau, 1992; U.S. Census Bureau, 2001). Counties with particularly high DVA densities were Douglas, Johnson, Leavenworth, Miami, Sedgwick, Shawnee, and Wyandotte, with Wyandotte having the highest DVA density for each year examined (KDOT, 2010). Using this information the following mitigation techniques could be directed at these counties and areas.

Possible Mitigation

Though hunting has been used as a method of deer population control (Brown et al., 2000), the results of this study suggest methods aimed at changing driver habits and awareness might be more effective in reducing DVAs. This is because, in most of the models, the factors found to be influencing DVAs were primarily human related. Sullivan et al. (2004) found that the use of temporary warning signs reduced the number of DVAs by 50% in known mule deer migration paths. Implementing similar signs along sections of roads with high DVA concentrations during the rut (the deer mating season), which is typically in November, could alert the drivers of the increased danger. The benefit of these signs versus the typical deer warning sign is that people likely become accustomed to the normal deer signs and stop paying attention. A flashing sign present only during the rut would be something that drivers are not accustomed to, so they might be more alert to the dangers of deer.

Another option could be implementing reduced speed limits on highways during the rut or close to sunset/sunrise, which is when most DVAs occur (Ross and McCullough, 1976). The slower speeds would allow drivers to stop sooner, thereby hopefully avoiding a DVA. The additional benefit of reduced speeds would be increased gas mileage, which could be used as an extra selling point for implementing this strategy. Fences could also be built along roads near bridges and gullies with high DVA concentrations and underpasses for deer could be constructed in conjunction with the fences in areas where it was deemed necessary.

Additionally, increasing education and deer awareness among drivers, specifically during driver education classes and when receiving a driving license, could be a relatively cheap and possibly effective means of changing driving habits and reducing DVAs.

Limitation of Study

One of the primary limitations of this study could be the accuracy of the data, specifically the reporting, or underreporting, of DVAs. While KDOT recommends reporting all accidents to local law enforcement officers, Kansas law only requires drivers to report accidents to the police if there has been an estimated $1,000 in damages, an injury, or death (Kansas Legislature, 2010). Otherwise it is up to the drivers' discretion to report an accident. Because of this law, there could be larger DVA reporting in the more densely populated counties in Kansas due to larger police force presence. Likewise, there might be less reporting of DVAs in more rural counties due to smaller police presence and the possible desire of the drivers to not involve the police.

Another potential limitation with the study is the possibility of poor record keeping influencing the overall DVA trends and distributions. Additionally, issues similar to this could have affected the other historic data used. Coupled with this, some variables that were originally included for the study (which included percent of land forested and vehicle traffic counts) had to be removed from the analysis as there were large gaps in the data or were in a format that was unusable. These potential limitations should be considered when viewing the results of this study and taken into account when conducting future DVA research using similar methods.

Future Work

Future work could go in two directions, that of a larger or smaller scale. Looking at a smaller scale, in the sense of maps, the study conducted for Kansas could be repeated in the surrounding states of Colorado, Missouri, Nebraska, and Oklahoma. Comparisons could then be made and possible explanations for why some of these states, Kansas and Nebraska, have higher DVA rates than others could be determined. While this could be useful for forwarding the overall knowledge base on DVAs, as a study of this size has yet to be conducted, a more helpful study for Kansas would be to examine DVAs at a larger scale and study DVA distributions in individual counties.

For the studies of the individual counties to be useful they would have to take on new qualities, as county level site studies on DVA factors have been heavily researched (Finder, Roseberry, and Woolf, 1999; Anderson, Grund, and Nielsen, 2003; Gonser and Horn, 2007; and Campa III, Riley, and Sudarsan, 2009). Rather than try to identify DVA factors in random counties, these studies should instead concentrate on counties with high DVA densities, such as Johnson, Leavenworth, Wyandotte, etc., and identify what mitigation techniques could be implemented. Going through and ranking the mitigation techniques based on possible effectiveness, cost, and where to implement them would provide a great benefit to the Kansas' wildlife and transportation agencies.

The ability of this type of study to be conducted would hinge on whether or not a researcher could gain access to individual accident site data, which would be difficult due to methods used to record the accident sites and issues of privacy. This type of study would also have to examine multiple years so that the accuracy of the study would increase, thereby reducing the chance of false patterns of high DVA concentrations showing up.

Contributions to Literature

Overall, my research contributed to the literature on DVAs in several different ways. I used GIS to generate spatial data particular to my study which would have been unavailable otherwise for my quantitative analysis. By doing this I demonstrated another use of GIS in DVA research, aside from in site studies, which further demonstrates the importance of this study. My study also reasserted the practicality of quantitative analysis in DVA investigations and that research at the county scale for a state can be successfully conducted.

Additionally, by studying a long time span I demonstrated that factors affecting DVAs can be consistent with time, as all my models had almost the same influential variables. This is something no other study within North America has done since DVA researchers have focused on one to five year time spans (Iverson and Iverson, 1999; Farrell and Tappe, 2007; Gonser, Jensen, and Wolf, 2009).

Conclusion

In conclusion, higher DVAs rates are a problem that has plagued Kansas for over 20 years. The results from this study showed that the primary factors responsible for the distribution of DVAs were human and infrastructure related. As such, mitigation techniques that are implemented should be directed towards modifying driver habits and limiting deer access to roads near bridges and other areas with high numbers of deer crossings. Additionally, mitigation methods should be targeted in areas in the eastern and central portions of Kansas, where the counties with the highest DVA densities are located. The use of multivariate regression analysis for this study was extremely effective and bodes well for its continued use in DVA research. Using this method and those mentioned above, future researchers can continue to gain a better understanding of DVAs and what can be done to stop them.

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VITA

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Scope and Method of Study:

This study uses multivariate regression analysis to gain a better understanding of what factors are influencing deer vehicle accident distributions in Kansas. The study examines an 17 year time span from 1992 to 2008, with the years 1992, 2001, and 2008 chosen to serve as snapshots for the overall time period. Variables associated with roads, land use, human, and deer populations are examined to determine how the influence of these factors affects the distribution of deer vehicle accidents throughout the state.

Findings and Conclusions:

Using multivariate regression analysis, the county level models revealed that the primary factors responsible for deer vehicle accident distributions are human related. Bridge density and human population density were the main factors influencing deer vehicle accident distributions for all the years examined. Additionally, percent of land used for hay, percent of land used for wheat, highway density, and deer harvest density were factors found influential in at least one or more of the yearly models. Overall, the types of factors and their level of influence in each of the models were fairly consistent for all the years, the exception being 1992 which saw the greatest variation in factor influence. From the results it is clear that mitigation techniques aimed at changing driver habits and increasing their awareness to the dangers posed by deer would be the most likely to secede at reducing deer vehicle accident rates in Kansas.

ADVISER'S APPROVAL: Dr. Brad Bays