ROAD CHARACTERISTICS THAT INFLUENCE THE INCIDENCE
OF LARGE MAMMAL-VEHICLE COLLISIONS ON
COLORADO STATE ROUTE 160A

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to the Faculty of
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Environmental Policy and Planning

by
Catherine R. Buttrey
Spring 2013
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ABSTRACT

ROAD CHARACTERISTICS THAT INFLUENCE THE INCIDENCE OF LARGE MAMMAL-VEHICLE COLLISIONS ON COLORADO STATE ROUTE 160A

by

Catherine R. Buttrey

Master of Arts in Geography

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The field of road ecology centers around the impacts that roads have on an ecosystem. Impacts affect wildlife, habitat, vegetation, and humankind. Transportation infrastructure fragments habitat and connectivity thus forcing wildlife to cross roads and risk being hit. Wildlife-vehicle collisions are a growing problem in the United States. As wildlife populations and vehicular travel both increase, collisions are increasing as well. Such collisions pose threats to human and wildlife safety. My objective in this study was to determine where accidents commonly occur along Colorado State Route 160A (Highway 160) and if the selected road characteristics affect the number of large mammal-vehicle collisions. The data for this research was acquired from the Colorado State
Patrol’s Wildlife Collision Database. For each large mammal-vehicle collision incident in the database there were associated road characteristic variables that included: road contour, road slope, speed limit, number of through lanes, center median width, city limits, annual average daily traffic, road condition, water drainages, and potential wildlife underpasses. These variables were analyzed in a generalized linear model to identify roadway characteristics which contribute to large mammal-vehicle collisions. The model as a whole was found to be significant with an adjusted $R^2 = 0.33$ and identified six road characteristics including – center median width, road contour, road condition, speed limit, water drainages, and potential wildlife underpasses as significant in predicting the number of large mammal-vehicle collisions. Future transportation planning should account for road characteristics that influence collisions and attempt to mitigate collisions in high risk areas.
CHAPTER I

INTRODUCTION

Background

Road ecology is a rapidly developing field of study that considers the effects of roads on an ecosystem. Some of the ecological effects of roads include: impacts on roadside vegetation, wildlife mortality, behavioral changes to wildlife, barrier effects, habitat fragmentation, and pollution (Forman and Alexander 1998). Some species types, such as scavengers, can benefit from roads; however, roads negatively affect the majority of species (Fahrig and Rytwinski 2009). Roads have long lasting impacts that affect the overall health of an ecosystem (Davenport and Davenport 2006). Transportation infrastructure often serves to fragment wildlife habitat and fracture ecosystem connectivity. Biodiversity is threatened as land is fragmented by a continually growing road system in the United States. To accommodate future growth, road ecology principles should be incorporated at the national, state, and local levels to accommodate wildlife connectivity in transportation planning and design.

Statement of the Problem

Roads serve as barriers to landscape connectivity that subdivide populations, alter genetics, and impair biodiversity. The “road effect zone,” or area
ecologically affected by a road, can extend outward up to 100 m from the road (Forman 2000). It is estimated that 15–20% of the land mass in the United States is directly affected ecologically by roads and this percentage is only expected to grow with time (Forman and Alexander 1998, Forman 2000). Road development has marred habitat connectivity, isolated populations, and obstructed gene flow. For instance, Epps et al. (2005) found over the past 40 years that roads contributed up to a 15% decrease in the genetic diversity of desert bighorn sheep. Connectivity allows for movement between patches, while habitat fragmentation isolates small populations, sometimes leading to local extinction (Hilty et al. 2006). Transportation infrastructure is not the only land use that serves to fragment species connectivity. Other land use changes such as agriculture, logging, mining, residential development, and commercial development have all served to further fragmentation (Hilty et al. 2006).

A notable effect of roads on the ecosystem is the extraordinary number of wildlife-vehicle collisions (WVC) that occur in the United States. White-tailed deer (*Odocoileus virginianus*) populations, vehicular travel, and collisions are all increasing annually (Hedlund et al. 2004). The number of WVCs increased by approximately 50% between 1990 and 2004, while the total number of motor vehicle crashes remained unchanged (Huijser et al. 2008b). The costs to wildlife populations, habitat, human life, and property damage are all substantial and pose both economic and safety threats as well as threats to the intrinsic value of wildlife and ecosystems. Steps must be made to mitigate the harm caused by WVCs in order to limit danger to both wildlife and humans.
Purpose of the Study

This study used information about where collisions occur along Highway 160 through 8 counties in southern Colorado to examine geographical patterns and road characteristics that correlate with high rates of WVCs (Figure 1). This study analyzed road characteristics and variables that influence the likelihood of collisions in an attempt to determine what geographic and road variables are correlated with most accidents and if those variables can predict higher collision potential. This research built upon past studies in other regions that have evaluated variables that increase or decrease the probability of WVCs.

Highway 160 was chosen because it has been identified as a highway with increasingly high rates of WVCs (CDOT Safety and Traffic Engineering, personal communication, October 2011). Large numbers of ungulates including *Odocoileus hemionus*, *Cervus canadensis*, and *Antilocapra americana* are killed along the highway by vehicles during seasonal movements and migrations. This poses not only a threat to the wildlife population but to motorist safety as well. There is minimal wildlife protection infrastructure currently in place along this section of Highway 160. One small underpass was constructed for lynx (*Lynx canadensis*) at mile 175.43. Wildlife fencing has been installed approximately between miles 65 – 66, 93.2 – 96, and 254.6 – 257.8. The fencing between miles 93.2 – 96 accompanies one of the first wildlife detection systems ever built and it was installed in 2010. Night-time speed reduction zones near wildlife corridors
Figure 1. Map of ~305 miles of Highway 160 across Montezuma, La Plata, Archuleta, Mineral, Rio Grande, Alamosa, Costilla, and Huerfano counties in southern Colorado.


were also implemented in 2010 between mile posts 113 and 121. Another highway with extraordinary WVC rates is Interstate 70 in northern Colorado. Unlike Interstate 70, which is already altered with permanent wildlife fencing, Highway 160 is still largely unaltered offering the opportunity to experimentally test new mitigation methods.
Limitations of the Study

This study was limited to Highway 160 between the years 2000 and 2010. Only data for vehicle collisions with large mammals were used because the data on collisions with small mammals and other wildlife are extremely limited and could skew my findings. I only analyzed geographic and road variables. I did not include temporal variables or habitat data because I wanted to focus on characteristics of the roadway not the seasonal variation, and because no habitat or vegetative coverage data were collected by State Patrol officers in wildlife-related accident reports. Data analysis evaluating WVC rates near the wildlife detection system and night-time speed reduction zones was not included because these studies have only recently been implemented and did not span all of the years that my database included.

Definition of Terms

- AADT – Annual average daily traffic
- CDOT – Colorado Department of Transportation
- DOT – United States Department of Transportation
- FHA – Federal Highway Administration
- GPS – Global positioning system
- Highway 160 – Colorado State Route 160A
- LMVC – Large mammal-vehicle collision
- OTIS - Online Transportation Information System
- WVC – Wildlife-vehicle collision
CHAPTER II

REVIEW OF THE LITERATURE

Wildlife Mortality Impacts

The number of WVCs that occur each year is a topic of great concern to both wildlife managers and traffic safety agencies. Over 300,000 large animal collisions are reported each year in the US and that number is rising by approximately 6,700 collisions per year (McGowen and Huijser 2009). Many WVCs are unreported, with some estimates placing the actual number of WVCs closer to 1-2 million per year and these collisions result in total costs of approximately $8 billion per year (including damage to vehicles, medical costs of injuries sustained, and clean-up) (McGowen and Huijser 2009). It is also important to note that WVCs are increasing despite the decrease in the number of registered vehicles in the United States between 2008 and 2011 (Federal Highway Administration 2008-2011). The majority of the species involved in WVCs are deer. Between 2006 and 2007, WVCs were comprised of 99.2% deer (Odocoileus virginianus/ Odocoileus hemionus), 0.5% elk (Cervus canadensis), and 0.3% moose (Alces alces) (Beckman et al. 2010). WVCs are a concern to wildlife managers, but they are also a concern for human safety. Between 1995 and 2004, the rate of human fatalities due to WVCs increased by 78% whereas the rate of human fatalities in collisions not involving wildlife increased by only
2.5% (Langley et al. 2006). Huijser et al. (2009b) determined the average cost of species specific collisions and found that each deer collision averaged $6,617, each elk collision averaged $17,483, and each moose collision averaged $30,760. These average costs accounted for vehicle repair, human injuries, human fatalities, towing, accident attendance, investigation, hunting value of the animal, and carcass removal and disposal. Using cost benefit analysis, Bissonette et al. (2008) found that investing in appropriate actions to reduce WVCs can produce positive net economic gains while improving safety.

Identifying Problem Areas

Identification of areas where animals are likely to be hit is an important step in planning effective mitigation measures to be taken during the implementation or modification of transportation infrastructure. WVCs share many characteristics that help planners predict areas of high collision density and thus mitigate for such risk in advance. The analysis of roadkill and collision data to identify wildlife collision problem areas and predict and prevent future collisions has become common. Ramp et al. (2005) and Bissonette (2007) suggest hotspot modeling using mortality data and GIS to determine where wildlife is likely to be killed and what variables correlate to collisions. Particular road and landscape variables often correspond to varying densities of WVCs. Some variables increase the probability of WVCs while others have been shown to decrease the probability of WVCs (Gunson et al. 2011). Variables can include speed limit, road width, vegetative cover, road conditions, lighting, etc. These
variables can be used to improve highway design and direct mitigation strategies in areas with high wildlife collision densities (Barnum 2003, Malo et al. 2004, Ramp et al. 2005). Planners can incorporate road variables that effectively mitigate risk and avoid road variables that increase risk when they are designing or modifying a road that will bisect a known wildlife corridor. Jaarsma et al. (2006) designed a traversability model to predict successful road crossings based on road, traffic, vehicle, and species variables. Such a model can be used as a guide when planning for wildlife connectivity across roads.

Characteristics of Wildlife-Vehicle Collisions

Comprehensive studies, such as the Federal Highway Administration (FHA)'s Wildlife-Vehicle Collision Reduction Study (Huijser et al. 2008b), have analyzed nearly every aspect of WVCs, including the causes and characteristics of WVCs. Several smaller studies have researched where collisions typically occur along specific stretches of highway and what variables are associated with those collision sites (Gunson et al. 2011). A collection of WVC research spanning several countries has found the following road, environmental, geographic, and temporal characteristics important in determining WVC risk.

Traffic volume is one variable that is often considered when attempting to determine collision potential. McGowen and Huijser (2009) found that collisions occurred more frequently on roads with low traffic volumes; yet, many other studies have found that collisions are more common on roads with high traffic volumes (Groot Bruinderink and Hazebrock 1996, Seiler 2003, Van
Highway speed limit is also a variable commonly used to estimate collision risk and most research agrees that high speed roads exhibit greater risk of WVCs (Groot Bruinderink and Hazebrock 1996, Gunther et al. 1998, Seiler 2003, Meyer 2006, Riley and Sudharsan 2006, Young et al. 2007, Sullivan 2009). High speed limits are often associated with straight roads, and straight roads are also related to greater incidence of collision (Langley et al. 2006, McGowen and Huijser 2009). In general, road designs that increase design speeds and straighten roads have even greater risk of WVCs (Gunther et al. 1998, Young et al. 2007). Road width is also an important variable in collision probability. Seiler (2003) showed that wider roads are associated with greater numbers of WVCs. Center medians often serve to add width to the total highway right of way. Medians have shown the potential to decrease collisions by giving the animal more time to cross; however, vegetation in the median might also serve to attract wildlife that would not normally be crossing the road (Clevenger and Kociolek 2006).

Road condition is a variable that may be assessed in collision studies. While icy or rainy roads may be a factor in particular collisions, the majority of WVCs occur on dry roads (Garrett and Conway 2000, Gunson et al. 2003, Langley et al. 2006, McGowen and Huijser 2009, Shao and Alhomidan 2010). The slope of the landscape topography is significant to consider in road design. A few studies have found that WVCs are more likely to occur on flat grades of road than inclines (Gunson et al. 2005, Klocker et al. 2006, Gunson et al. 2011).
Proximity to wildlife habitat and cover is a key variable in determining WVC risk for a road. Wildlife presence in the right of way increases when habitat abuts a highway (Gunther et al. 1998, Malo et al. 2004, Riley and Sudharsan 2006, Shao and Alhomidan 2010). Collisions have also been shown to occur more frequently near water drainages (Clevenger et al. 2001a, Rogers et al. 2004, McGowen and Huijser 2009). This may be because water drainages serve as a source of water, food, and shelter and often act as a natural landscape funnel for wildlife movement. Rural roads tend to bisect wildlife home ranges and this may explain why such roads have greater incidence of WVCs (Langley et al. 2006, Huijser et al. 2007). The fact that rural roads also tend to have fewer lanes than major highways could justify why Langley et al. (2006) and McGowen and Huijser (2009) both found that stretches of road with only one or two lanes experience more WVCs.

WVCs at the start of hunting season. This rise in collisions is potentially linked to
greater disturbance from hunting. WVCs have also been shown to increase
during the spring and early summer which correlate with spring migrations (Groot

Crossing Selection and Siting

The selection of a proper location for a wildlife crossing is essential to
its use as a functional mitigation measure (Clevenger and Huijser 2011).
Placement of wildlife crossings near historic movement corridors is vital to
encouraging the utilization of infrastructure by target species (Foster and
Humphrey 1995). If a crossing is placed in an area that is not compatible with a
species movement corridor the crossing will not be functional and the mitigation
will be useless. According to Beckmann et al. (2010), crossing selection and
siting can be based on many variables such as topography, species expected to
use the crossing, adjacent land use, and location in the landscape corridor
network. Wildlife corridors often follow the topography of the land meaning that
topography can serve to funnel wildlife across a road in a particular area.
Species-specific size requirements and behavioral characteristics are also
important factors to consider in the selection and design of a particular crossing.
Particular species will only use crossings that fit their preferred length, width, and
height ratios, also known as openness ratios (Gordon and Anderson 2003,
Clevenger and Waltho 2005). The interval spacing between crossings is also
important in determining use. If crossings are too close together, infrastructure
funding is wasted. If crossings are too far apart, landscape permeability will be impaired. Spacing between crossings should align with the target animal’s home range (Huijser et al. 2008a). This goes along with Bissonette’s (2007) suggestion to use allometric scaling to site crossings. Allometric scaling determines ecologically scaled crossing location by considering the species present in the area as well as the home ranges and dispersal distances of those species. Mitigation measures should be comprehensive and considered in the context of the landscape (McGowen and Huijser 2009). Project based linkages should connect to larger scale landscape connectivity plans and incorporate projected land use change. It is necessary to consider the temporal and spatial context in planning so that a crossing can remain functional over time (Beckmann et al. 2010).

Mitigation Measures

There are a variety of mitigation measures aimed at reducing WVCs. Types of wildlife crossing structures include: landscape bridges, wildlife overpasses, multiuse overpasses, canopy crossings, viaducts, large mammal underpasses, multiuse underpasses, underpasses with water flow, small to medium sized mammal underpasses, modified culverts, amphibian and reptile tunnels with drift fence, as well as large fauna fencing with gates, doors, ramps, and jump outs (Beckmann et al. 2010). Mitigation measures can be aimed at modifying animal behavior, modifying driver behavior, or both. Huijser et al. (2007) explain that while there are many different types of mitigation measures to
decrease collisions, few perform well. The only consistently effective mitigation measure in reducing WVCs is fencing in combination with crossing structures (Hedlund et al. 2004, Knapp et al. 2004).

**Structural Mitigation**

Wildlife fencing has proven to be one of the most effective mitigation measures in reducing collisions; yet, without proper crossing structures in combination with fencing, fencing alone can fragment habitat and decrease wildlife connectivity (Beckmann et al. 2010). Crossings allow wildlife to cross roads while decreasing hazards to both wildlife and motorists (Foster and Humphrey 1995). Wildlife fencing keeps wildlife out of the highway right of way and promotes the use of crossing structures (Dodd et al. 2007). Crossings combined with fencing can decrease road mortality and connect populations (Clevenger et al. 2001b). Depending on the rate of road mortality, fencing can either be beneficial or detrimental to population persistence across roads. Olsson and Widen (2008) studied moose permeability across a highway pre and post fencing and crossing implementation. Results showed that collisions decreased after fencing implementation. Moose permeability also significantly decreased because the fencing served as a barrier to habitat connectivity. Braden et al. (2008) found that deer range and movement was similar before and after fencing and structure implementation and collisions decreased by 94% inside the fenced section of highway. Dodd et al. (2007a) established that the implementation of crossing structures and ungulate proof fencing decreased collisions by 86.8% while improving overall elk permeability. Clevenger et al. (2001a) determined that
wildlife fencing in addition to crossings decreased collisions by 80%. Huijser et al. (2010) recorded a 47% decrease in collisions after fencing, jumpouts, and crossing structures were implemented. Jaeger and Fahrig (2004) found that fences benefit population persistence when road mortality is high and fences inhibit population persistence when road mortality is low. Some studies have failed to prove that fencing decreases WVCs. Feldhamer et al. (1986) documented that fencing decreased the number of deer in the right of way but it did not lower the number of collisions. Fencing effectiveness depends on maintenance and repair (Bissonette and Hammer 2000). Donaldson (2005) has concluded that the savings in property damage from reduced collisions far exceeds the cost of structure construction.

A method of escape from the highway right of way is essential when implementing wildlife fencing. Fencing along a transportation corridor can serve to keep wildlife out of the highway right of way, but it can also serve to trap wildlife within the right of way when wildlife manage to bypass fencing and end up inside the corridor. Good planning provides escape routes in combination with barriers (Huijser et al. 2008b). The two most common types of escape routes are one way escape gates and earthen ramps but one-way escape gates have been proven largely ineffective (Lehnert and Bissonette 1997). Ramps are becoming more common and are preferred over gates because of their greater effectiveness (Bissonette and Hammer 2000).

Highway crosswalks in combination with fencing have proven to be effective in reducing WVCs. One study found that fencing and a crosswalk
effectively reduced deer use of the highway right of way and deer were observed using the crosswalk. Seasonal deer movements were left intact because of the crosswalk (Lehnert and Bissonette 1997).

Long bridges and tunnels are elevated roads or roads that are placed under the landscape. These roads are hundreds of meters long and leave the landscape and its associated ecological processes intact. By separating animals from traffic there is a total elimination of collisions (Beckmann et al. 2010). Due to their high cost, long bridges and tunnels are rarely built specifically to decrease WVCs (Huijser et al. 2009b).

**Mitigation Aimed at Changing Animal Behavior**

Removal of roadside vegetation decreases animal presence near the road by eliminating forage and/or cover. Vegetation removal also increases driver visibility of the roadside and allows drivers more time to react to wildlife on or near the road. Methods of decreasing vegetation quality include: planting unpalatable or thorny species along roadsides and medians, removing favorable foraging vegetation or plants that provide cover, mowing and cutting, and using noxious chemicals (Groot Bruinderink and Hazebrock 1996, Putman 1997, Evink 2002, Riley and Sudharsan 2006). Vegetation removal has proven to be very effective when used in combination with other mitigation measures. Andreassen et al. (2005) found that intercept feeding, placing alternative food sources away from the road, in combination with vegetation removal led to a 46% decrease in moose-train collisions. Vegetation removal along a 20-30 meter buffer on each
side of a railway decreased moose-train collisions by 56% (Jaren et al. 1991). It is important to make informed decisions when removing roadside vegetation because the timing of cutting can reduce the nutritional quality of regrowth and some types of regrowth can actually attract browser species (Rea 2003, Beckmann et al. 2010). While vegetation removal has proven effective, thought must be given to the infinite cost of vegetation removal as the removal of vegetation requires ongoing maintenance.

Wood and Wolfe (1988) found that intercept feeding decreased WVCs in Utah by up to 50%. Luring wildlife away from the road is only a short term solution. It is labor intensive, animals become dependent on the supplementary food, and population sizes typically increase. Intercept feeding is not suggested for long term use as mitigation measure.

Where salt is used to de-ice road surfaces, the runoff into swales and basins can become roadside salt licks which may attract wildlife to the road (Miller and Litvaitis 1992). Fraser and Thomas (1982) found that half of the moose collisions identified in their study were located at or near salt pools. Removing salt pools or utilizing other materials to de-ice roads can decrease wildlife attraction. A model designed by Grosman et al. (2009) displayed that removing salt pools decreased moose road crossings. This study recommended the removal of all salt pools without supplementing salt away. This would force wildlife to acquire natural salt from aquatic plants.

A variety of deterrents seek to repel wildlife away from the highway right of way. Reflectors aim to scare deer away from the road. They reflect
headlights off the roadway and into the right of way (Beckmann et al. 2010).

Many studies have found no evidence that reflectors decrease WVCs or increase avoidance behaviors (Reeve and Anderson 1993, Groot Bruinderink and Hazebrock 1996, Cottrell 2003, Rogers et al. 2004, D'Angelo et al. 2006). Some studies have tested olfactory repellents in deterring wildlife away from highways. Common repellants showed no effect or the effect diminished with habituation (Groot Bruinderink and Hazebrock 1996, Brown et al. 2000, Nolte et al. 2001). No studies have concluded that whistles and other acoustic devices produce lasting behavioral changes in deer (Romin and Dalton 1992, Groot Bruinderink and Hazebrock 1996, Ujvari et al. 2004, Valitzski et al. 2007). Most times hazing is ineffective or wildlife habituate to the hazing with time (DeNicola et al. 2000, Kloppers et al. 2005, VerCauteren et al. 2006, Beckmann et al. 2010). Lighting alone may serve to deter animals from the roadway. Studies have found decreased collision rates (up to 65%) along lighted roadways; though, it is unclear if reductions are due to increased visibility or animal light avoidance (McDonald 1991).

Population control has proven effective in reducing WVCs; nevertheless, this method of mitigation is often viewed as controversial and met with opposition. The three main methods of population control are antifertility, translocation, and culling. Antifertility injections can be effective at limiting deer populations, but the injections can disrupt normal reproductive behavior, cause physical problems, and incite overall behavioral changes (Turner et al. 1996, McShea et al. 1997). Antifertility is costly and repeated application is necessary.
(Huijser et al. 2009b, Beckmann et al. 2010). Another method of population control is translocation. Translocation requires that individuals be repeatedly relocated over time (Beckmann et al. 2010). Translocation is costly and carries higher capture related mortality risks (Cromwell et al. 1999, Beringer et al. 2002). In some species the translocated individual will often seek to return to the area where they were collected. Culling reduces the population by killing individuals. Significant herd reduction has shown effective in reducing WVCs (Doerr et al. 2001, Hedlund et al. 2004). However, culling is not sustainable. It requires ongoing population control via human interference. Without continued culling, populations will return to their original size and the initial culling efforts will have been useless. Another issue to consider is the impact that human modification of one population will have on other species in an ecosystem. Controlling one species will inevitably affect the predator species that rely on the controlled species as well as the prey species whose population was kept in check by the species being controlled (Rockwood 2006).

Mitigation Aimed at Changing Driver Behavior

A variety of programs have attempted to educate the public about wildlife movements in an attempt to decrease WVCs. While many will agree that it is still important to educate the public about WVC risk and animal movements, it is unlikely that such programs will decrease the number of collisions (Groot Bruinderink and Hazebrock 1996, Beckmann et al. 2010).
Wildlife warning signs are a common primary attempt at modifying driver behavior in order to mitigate WVCs. There are many different types of signage. It is standard practice among transportation professionals to install signs when WVCs are high (Knapp and Witte 2006). Permanent signage is left in place year round. Enhanced signage is in place year round but may include lights or animations that flash at certain times. Seasonal warning signs are temporary and are often placed during periods of animal movement, such as migrations (Beckmann et al. 2010). The effectiveness of signage varies. Pojar et al. (1975) found that signage decreased vehicle speed, but it failed to reduce WVCs. Sullivan et al. (2004) reported that temporary enhanced seasonal signage decreased deer collisions by 51%. Yet, multiple studies have found that permanent warning signs show no evidence of reducing WVCs (Groot Bruinderink and Hazebrock 1996, Rogers et al. 2004, Meyer 2006). This is likely due to driver habituation (Sullivan et al. 2004, Beckmann et al. 2010).

Animal detection systems are one of the newest forms of WVC mitigation. These systems use sensors to detect large animals which then trigger automated signs warning drivers to slow down. This method of mitigation offers a time specific warning (Beckmann et al. 2010). In order to be effective, it is important for the system to function properly and detect all large animals without frequent false warnings. If it is consistently unreliable, driver confidence in the system will decrease (Huijser et al. 2009a). Some studies have shown these systems to be largely effective, while other studies suggest that the systems still require further research and modification. Mosler-Berger and Romer (2003)
found a detection system to be 82% effective in decreasing collisions. One of the benefits of detection systems is that they are only active for a small portion of the day and thus provide a more time-relevant warning. Habituation to permanent signage is less likely to occur with presence activated warning signs; still, effectiveness of detection systems in decreasing WVCs depends on driver alertness, response, and decrease in speed (Beckmann et al. 2010). Detection systems are most effective when combined with other mitigation measures. Dodd and Gagnon (2008) recorded a 91% reduction in collisions following the implementation of wildlife fencing, underpasses, and a crosswalk with a detection system. Maintenance and monitoring of such systems are essential to their effectiveness (Dodd and Gagnon 2008).

Reduction in vehicle speed has been associated with decreased collision risk. Lower speeds allow drivers and wildlife more time to respond and avoid collisions. As traffic speed increases, the potential for a WVC increases (Seiler 2003, Riley and Sudharsan 2006). Gunther et al. (1998) found that vehicle speed was the principal variable contributing to WVCs in Yellowstone National Park. Jones (2000) discovered that a species was able to recover by 50% of its original population following speed reduction measures. Bertwistle (1999) concluded that speed reduction zones significantly decreased elk-vehicle collisions. Changes in road design are likely to be more effective than simply lowering the signed speed limit (Beckmann et al. 2010). It is best to reduce vehicle speeds through the use of traffic calming measures in addition to lower signed speed limits.
Reducing traffic volume on roads has been shown to decrease collisions. Roads with higher traffic volumes appear to have more WVCs (Seiler 2003, Riley and Sudharsan 2006). A model by Van Langevelde and Jaarsma (2004) showed a positive relationship between traffic volume and increased collisions. However, Groot Bruinderink and Hazebroek (1996) and Hubbard et al. (2000) found no direct relationship between traffic volume and WVCs. A model simulating wildlife population persistence showed that it is better to have higher traffic flow on one road or multiple roads in close proximity than to have multiple roads spread across the landscape with lower traffic volumes. This is because landscape fragmentation and patch isolation is less severe when traffic is consolidated (Jaeger et al. 2005).

Monitoring

The effectiveness of mitigation measures can be determined by conducting pre and post mitigation studies. The collection of baseline data is essential for reference in future studies. Monitoring methods for WVCs include: carcass removal counts by road crews, WVC reports by highway patrol, and driving surveys. Crossing structures can be monitored through the use of: video or still cameras, track beds, track plates, hair collection for DNA analysis, mark recapture, and GPS collaring. Monitoring for at grade highway crossings can include: video or still cameras, track beds, snow track transects, and GPS collaring (Clevenger and Huijser 2011). Monitoring programs should be carried out year round over long periods of time to determine local and landscape level
benefits; however, short term monitoring programs can still yield valuable data (Clevenger and Waltho 2003, Beckmann et al. 2010).

Crossing structure use by wildlife can be affected by a variety of factors. Wildlife use of crossing structures is largely affected by noise. Structure use declines when elevated traffic volumes amplify noise (Dodd et al. 2007, Gagnon et al. 2007, Olsson et al. 2008). Human disturbance adjacent to a crossing also negatively affects wildlife use of structures (Clevenger and Waltho 2000, Dodd et al. 2007, Mata et al. 2008). The performance level of a structure depends on the purpose and the species for which it was built (Clevenger 2005). Certain species prefer particular openness (height to width) ratios, percentage of vegetative cover, and through visibility (Foster and Humphrey 1995, Clevenger and Waltho 2000, Gordon and Anderson 2003, Clevenger and Waltho 2005, Donaldson 2005, Kleist et al. 2007, Mata et al. 2008, Glista et al. 2009). Donaldson (2005) found that structures with water drainages incorporated into their design encourage use by wildlife. Structures are used the most at night when the majority of wildlife movement occurs (Olsson et al. 2008). Most crossings are not specifically designed for wildlife but existing infrastructure may be adapted for wildlife use (Donaldson 2005, Kleist et al. 2007, Mata et al. 2008). It is important to note that structure use commonly improves over time as wildlife habituate to the structure (Braden et al. 2008).
CHAPTER III

METHODOLOGY

Design of the Investigation

The main objective of my analysis was to determine if the number of LMVCs along Highway 160 was affected by the selected road characteristics. McGowen and Huijser (2009) have suggested that more research is needed in regard to reduced speed limit, reduced traffic volume, and expanded median. I also wanted to determine where accidents commonly occur along Highway 160 between the Colorado/New Mexico border near Four Corners and the town of Walsenberg, Colorado, located just west of Interstate 25 in southeastern Colorado. The highway spans 305.38 mi (491.46 km) across southern Colorado through rolling hills, plains, and mountainous terrain. Highway 160 summits both Wolf Creek Pass in the San Juan National Forest and La Veta Pass in the Rio Grande National Forest. Speed limits along the highway range from 25 MPH to 65 MPH. AADT along segments of the highway varies from 100 to 38,000. Highway 160 traverses through 11 cities and 8 counties. This study analyzed data generated from WVC reports collected along this stretch of Highway 160.
Treatment

The data for this research was acquired from the Colorado State Patrol’s Wildlife Collision Database. See Appendix A for a copy of the State of Colorado Traffic Accident Report form. I gained access to this database from CDOT Headquarters for Safety and Traffic Engineering in Denver, Colorado. The database query that I was given included every WVC that was reported to the Colorado State Patrol between 2000 and 2010. An abundance of variables that ranged from weather conditions to driver demographics and wildlife species were attached to each collision. The parameters I used in determining what information I would use from the database included: highway, contour, slope, condition, speed limit, and species of animal. I limited my research to Highway 160 in southern Colorado because it is well known for a high incidence of WVCs, and few studies have analyzed the issue on this highway. After narrowing the database down to only Highway 160, I eliminated all collision variables that were not relevant to my research questions. These included all human variables and vehicle details collected in the accident report. Human variables included injury levels, involvement of drugs or alcohol, seatbelt use, driver age, driver sex, and driver's state of home residence. Vehicle details included vehicle type, vehicle speed, and vehicle direction of movement. I also reduced my study to focus on large mammals due to the lack of reporting for small animal collision data, which may have skewed the significance of my results.

The database was also missing some variables for data, which I felt would be beneficial to my study. For this, I accessed the CDOT’s OTIS as well as
Google Earth to fill in any speed limit, contour, or slope fields that were left blank during the collision data information collection. I also acquired additional road variables by querying the OTIS system and integrated these variables into the collision database. The following variables were merged with the collision database relative to each mile post: number of through lanes, center median size, presence or absence of a city, AADT, drainages, bridges, and large structures. Information for wildlife related structure locations was provided by CDOT Region 5 engineers. I also used OTIS to verify database fields for accuracy.

My hypothesis was that as road contour, slope, speed limit, number of lanes, center median width, and AADT increased, the number of LMVCs would increase. I also hypothesized that city limits and water drainages would be positively correlated with collisions while potential wildlife underpasses would be negatively correlated with collisions.

Data Analysis Procedures

The number of accidents along Highway 160 was plotted against the mile post numbers associated with each collision to create a graph of collision density per mile post. Mean collision density per mile was calculated by averaging the total number of collisions in the dataset by the total number of miles in the segment of highway.

For each LMVC incident in the database there were associated road characteristic variables that included: road contour, road slope, speed limit,
number of through lanes, center median width, city limits, AADT, road condition, water drainages, and potential wildlife underpasses. Water drainages were defined as a drainage or water flow under a road that was not large enough for a large mammal to traverse beneath. Potential wildlife underpasses were defined as a bridge over a span of land or water that was large enough for a large mammal to traverse beneath. Each road variable was broken down into varying levels for database analysis (Table 1).

Table 1. Road variables and levels of categorization

<table>
<thead>
<tr>
<th>Road Variable</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Contour</td>
<td>Curve, Straight</td>
</tr>
<tr>
<td>Road Slope</td>
<td>Grade, Level</td>
</tr>
<tr>
<td>Road Condition</td>
<td>Dry, Wet, Snowy, Icy</td>
</tr>
<tr>
<td>Through Lanes</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td>Speed Limit</td>
<td>Low, Medium, High*</td>
</tr>
<tr>
<td>AADT</td>
<td>Low, Medium, High**</td>
</tr>
<tr>
<td>Center Median Width</td>
<td>None, Small, Large***</td>
</tr>
<tr>
<td>City</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Water Drainage</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Potential Wildlife Underpass</td>
<td>Yes, No</td>
</tr>
</tbody>
</table>

*Speed Limit Ranges from Low to High: < 45, 45 – 55, > 55
**AADT Ranges from Low to High: < 12,000, 12,000 – 25,000, > 25,000
***Center Median Width Ranges for Small and Large: 1 – 10 ft, 10 – 26 ft

I summed the number of LMVCs for each permutation of the road characteristics. For example, one category would be a water drainage, 2 through...
lanes, road contour straight, road slope level, speed limit low, center median small, not in a city, AADT low, and road condition dry. There were 200 categories describing different combinations of the predictor variable levels. These sums, or counts, were the response variable in my analysis. Initial quantile plots and histogram plots of the response variable revealed that the response was not normally distributed. After performing a Box-Cox Test and transforming the data to -0.4\textsuperscript{th} power they were normally distributed based on the final quantile and histogram plots.

I used Proc GLM in SAS 9.2 (SAS Institute 2009) to fit a generalized linear model to test for effects of the road characteristics on the number of LMVCs. Significance for the analyses was set at alpha level 0.05.
CHAPTER IV

RESULTS AND DISCUSSION

Presentation of the Findings

The Wildlife Collision Database was queried to compile a total of 3,140 LMVCs between January 1, 2000, and December 31, 2010, along Highway 160. Species involved in the collisions included: mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), pronghorn (*Antilocapra americana*), black bear (*Ursus americanus*), and mountain lion (*Puma concolor*). Deer were the most common species involved in collisions (88%), while elk were the second most abundant species found in collisions (10%). Bear, antelope, and mountain lion were each involved in < 1% of the total collisions. The overall collision density along Highway 160 averaged 10.28 collisions per mile (6.39 / km) over an eleven year span (Figure 2). High collision densities were clustered in specific sections of Highway 160 (Figure 3).

The overall initial model was highly significant ($P<0.0001$), however several individual predictors were non-significant. I used backwards stepwise elimination, whereby the least significant term in the analysis was eliminated and the model re-run until all terms were significant. After all of the predictors were established as significant, the model as a whole was found to be significant.
Center median width, road contour, road condition, speed limit, water drainages, and potential wildlife underpasses were all significant in predicting the number of LMVCs (Table 2). Variables for number of through lanes, city limits, road slope, and AADT were all found to be non significant and were thus removed from the final model. The final model analyzed the number of collisions along Highway 160 using the road variables: center median width, road contour, road condition, speed limit, water drainages, and potential wildlife underpasses.

Odds ratios were calculated for the road characteristic variables using the parameter estimates (Table 3). The odds ratios found that wider center
medians were associated with greater odds of a collision. Also, collision risk increased with road sinuosity. Icy roads were the most likely to be involved in a collision when compared to dry roads. Snowy roads were the least likely to be involved in a collision when compared to dry roads and wet road odds were between icy and snowy road odds. Collision probability was higher near both water drainages and potential wildlife underpasses. The model also found that collisions were less likely to occur as speed limits increased.
Table 2. Significance of the variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter Estimate</th>
<th>Standard Error</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.68977</td>
<td>0.05052</td>
<td>13.65</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Large Center Median</td>
<td>0.17136</td>
<td>0.04850</td>
<td>3.53</td>
<td>0.0005</td>
</tr>
<tr>
<td>Small Center Median</td>
<td>0.13977</td>
<td>0.04304</td>
<td>3.25</td>
<td>0.0014</td>
</tr>
<tr>
<td>Curve in Road</td>
<td>0.16887</td>
<td>0.03825</td>
<td>4.41</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Icy Road</td>
<td>0.36838</td>
<td>0.08833</td>
<td>4.17</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Snowy Road</td>
<td>0.28842</td>
<td>0.08845</td>
<td>3.26</td>
<td>0.0013</td>
</tr>
<tr>
<td>Wet Road</td>
<td>0.29678</td>
<td>0.04805</td>
<td>6.18</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Water Drainage</td>
<td>0.17469</td>
<td>0.05579</td>
<td>3.13</td>
<td>0.0020</td>
</tr>
<tr>
<td>Potential Underpass</td>
<td>0.19794</td>
<td>0.08607</td>
<td>2.30</td>
<td>0.0226</td>
</tr>
<tr>
<td>High Speed Limit</td>
<td>-0.36277</td>
<td>0.05476</td>
<td>-6.63</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Medium Speed Limit</td>
<td>-0.21184</td>
<td>0.05418</td>
<td>-3.91</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Discussion of the Findings

According to the model, six variables (center median, contour, condition, drainage, underpass, and speed) were found to be significantly correlated with LMVCs and four variables (slope, lanes, city, and AADT) were found to be non significant.

Center median width was positively correlated with an increase in collisions. Fewer collisions were evident in stretches of highway that had smaller center medians. The literature is scare regarding center median width impacts on wildlife collisions. Huijser et al. (2008b) suggest that wide medians give animals a
Table 3. Variable odds ratios

<table>
<thead>
<tr>
<th>Response Variable</th>
<th>Odds Ratio</th>
<th>Reference Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Center Median</td>
<td>1.19</td>
<td>No Median</td>
</tr>
<tr>
<td>Small Center Median</td>
<td>1.15</td>
<td>No Median</td>
</tr>
<tr>
<td>Curve in Road</td>
<td>1.18</td>
<td>Straight Road</td>
</tr>
<tr>
<td>Icy Road</td>
<td>1.45</td>
<td>Dry Road</td>
</tr>
<tr>
<td>Wet Road</td>
<td>1.35</td>
<td>Dry Road</td>
</tr>
<tr>
<td>Snowy Road</td>
<td>1.33</td>
<td>Dry Road</td>
</tr>
<tr>
<td>Water Drainage</td>
<td>1.19</td>
<td>No Drainage</td>
</tr>
<tr>
<td>Potential Underpass</td>
<td>1.22</td>
<td>No Underpass</td>
</tr>
<tr>
<td>High Speed Limit</td>
<td>0.70</td>
<td>Low Speed Limit</td>
</tr>
<tr>
<td>Medium Speed Limit</td>
<td>0.81</td>
<td>Low Speed Limit</td>
</tr>
</tbody>
</table>

break from crossing several lanes of moving traffic and may therefore decrease collision risk. Other studies support the idea that center medians show the potential to decrease collisions by giving animals more time to cross the road (Clevenger and Kociolek 2006). Clevenger and Kociolek (2006) also noted that vegetation in the center median may serve as an attractant to wildlife that would not normally be crossing the road. Because my model analyzed center medians as a factor in road width, wider roads would appear to have more collisions. This is supported by Seiler's (2003) finding that greater road width is associated with larger numbers of collisions. This makes intuitive sense because the farther an
animal has to traverse across a road, the longer it will expose itself to being struck by a vehicle.

Road contour was found to be positively correlated with LMVCs. The model found that a vehicle would be more likely to collide with an animal in a curved section of road instead of a straight section of road. Shortened reaction time and visibility in a curve would explain these results; yet, this is contrary to previous studies that have found the greatest collision numbers on straight roads (Langley et al. 2006, McGowen and Huijser 2009). Other studies have pointed to the fact that the increased design speed of straightened roads often lead to more collisions (Gunther et al. 1998, Young et al. 2007, Huijser et al. 2008b). These differences in findings may be attributable to landscape topography and species migration patterns that are unique to the area.

Road condition results from the models suggested that collisions are more probable when weather is affecting the road surface. Icy roads showed the greatest correlation with LMVCs followed by wet conditions and then snowy conditions. Icy roads are often the most dangerous conditions for driving regardless of wildlife collision risk, so it would be justifiable that an icy road in an area prone to wildlife collisions would exhibit a greater potential for collision. Also, highway engineers often spread salt in areas that are prone to ice; and, residual salt in icy areas may attract animals to the road and thus increase collision probability. Snowy roads often have less traffic than wet roads and vehicle speeds on snowy roads are more likely to be slower than vehicle speeds on wet roads. Higher speeds and more vehicles would account for wet roads
having a greater probability of collision than snowy roads. According to the literature, dry road conditions are often characteristic of wildlife collision reports (Langley et al. 2006, McGowen and Huijser 2009, Shao and Alhomidan 2010). This may be because vehicles travel at the fastest speeds during dry road conditions, therefore reducing their reaction time to avoid collision with an animal.

Water drainages were positively correlated with LMVCs. Animals often follow water drainages as they move across the landscape in order to maintain a source of hydration and food. When water drainages eventually intersect a road they are often funneled beneath the road in a culvert. If an animal cannot follow the drainage under the road it is then forced to cross the road and thereby increases its chance of being struck by a vehicle. These results are confirmed with other findings that proximity to a drainage increases collision probability (Clevenger et al. 2001a, Rogers et al. 2004, McGowen and Huijser 2009).

Potential wildlife underpasses were also positively correlated with LMVCs. This may be because wildlife are hesitant about crossing under a highway bridge or other manmade structure. The potential wildlife underpasses in the database were mostly bridges over large spans of water and it may be that wildlife are traveling along the riparian corridor and not necessarily down in the riverbed. If wildlife are traveling along the corridor it would necessary to cross roads and thus increase their collision probability. It has been shown in the literature that existing infrastructure can be adapted for wildlife use (Mata et al. 2008) and most crossings are not specifically designed for wildlife (Donaldson 2005). Kleist et al. (2007) monitored a bridge with video surveillance to determine
its use as a wildlife underpass. They found that bridge size and design promoted its use as an underpass by wildlife, and bridges that are utilized by wildlife as underpasses benefit corridor connectivity. However, wildlife must be traveling along a route that naturally goes beneath a bridge in order for it to be utilized as an underpass without the necessitation of fencing to funnel wildlife that are traveling on nearby routes.

Greater speeds were negatively correlated with LMVCs. The model showed that fewer collisions occur at higher speeds. This is contrary to many studies that have found high speed roads to have greater risk of wildlife collisions (Groot Bruinderink and Hazebrock 1996, Gunther et al. 1998, Seiler 2003, Meyer 2006, Riley and Sudharsan 2006, Young et al. 2007, Sullivan 2009). Reduction in vehicle speed is most often associated with decreased collision risk because lower speeds allow drivers and wildlife more time to respond to and avoid collisions (Beckmann et al. 2010). The model's findings may be justified because speed limits are generally set higher in low risk areas where visibility is greater and roads are straighter. This would go along with the model's findings about contour that were also contrary to most research. Typically in other studies high speeds on straight roads have shown to exhibit the most risk for a collision. This model found that low speeds and curved roads are both correlated with more collisions. Curved roads generally have lower speed limits and more wildlife habitat, but people are more likely to ignore speed limits in curves and drive faster than is safe for the road topography. Multicollinearity between the variables
of speed limit and road contour may account for the model’s conclusions that are divergent from previous studies.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Six variables (center median, contour, condition, drainage, underpass, and speed) were significant predictors of LMVCs on Highway 160. The model predicted that sections of road with wider center medians would have more collisions. Road sinuosity was also positively correlated with collision potential. Icy roads were expected to display the most collisions. Water drainages and potential wildlife underpasses were both found to be present in areas with higher collision rates. Areas with lower speeds were found to have the highest collision probability. Most WVC studies have focused on temporal or habitat variables in predicting collision potential. This research offers insight into road variables that are often neglected in WVC studies. While some of my findings may go against what little research has been conducted on road variables, it is still valuable analysis that may be utilized for replication in the future.

Conclusions

Transportation planners must incorporate road ecology principles into future infrastructure design and implementation. Center medians should be
avoided whenever possible to shorten the distance that an animal must traverse across a road. In this study, it is likely that road sinuosity was greater in areas with more LMVCs because the rural, winding terrain along Highway 160 is also the same habitat area for much of the wildlife that is hit. Straight sections of Highway 160 are located in the plains where fewer wildlife species are prone to collision. Sinuous stretches of Highway 160 offer slower speed limits and greater populations of wildlife. Straight segments of the highway offer higher speed limits and fewer wildlife populations. Icy roads are most common in the high elevation areas where wildlife are found along Highway 160. Also, drivers are often caught off guard by icy conditions and may have less control when attempting to avoid collision. Water drainages and wildlife underpasses both facilitate wildlife movement by acting as natural landscape corridors.

**Recommendations**

Addressing wildlife connectivity early in the transportation planning and resource management process is essential to preventing future detrimental impacts. Much of previous transportation and connectivity planning has focused on addressing issues at the project scale. Current planning trends are realizing the importance of addressing issues at a broader ecosystem, or landscape scale (Clevenger and Huijser 2011). The integration of transportation and ecosystem planning at the landscape level benefits both habitat conservation and landscape connectivity (Clevenger 2005). Integrated planning is the foundation for an effective ecosystem planning approach.
When planning for connectivity at an ecosystem level, interagency cooperation and stakeholder collaboration is essential (Evink 2002, Reuer 2007). Interagency collaboration seeks to reach a common goal of ecosystem connectivity (Clevenger 2005). Transportation agencies, natural resource agencies, and land management agencies must all work together to align the needs of land use and conservation while assuring that crossings will remain functional over time. Public support and multi-agency involvement is crucial to the success of large scale linkage efforts (Servheen et al. 2007). Local support often determines the success of a project (Hilty et al. 2006). Kintsch et al. (2011) suggest a collaborative ecosystem approach to wildlife connectivity planning that aims to protect and restore wildlife connectivity, streamline the environmental review process, and involve stakeholders at all levels of the planning process. Such planning necessitates the designation of linkages, the incorporation of such linkages into future connectivity planning, and the monitoring of linkages for the purpose of adaptive management.

Adaptive management determines performance of existing connectivity and uses the results to inform future planning (Brown 2006). Adaptive management can help planners to be efficient by applying lessons learned from monitoring previous projects to the revision of future projects. Effective mitigation requires planning at a large scale for permeability through the use of adaptive management (Bissonette 2007). Adaptive management can determine successful connectivity projects by monitoring the sites post construction and then using the data to inform future planning and design.
REFERENCES
REFERENCES


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Describe Accident

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<td>Carrier Name</td>
<td>US DOT</td>
<td>ICC</td>
<td>State DOT</td>
</tr>
<tr>
<td>Address</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Carrier Identification #
### FEDERAL MOTOR CARRIER INFORMATION

#### AA. CARRIER TYPE
01. Intrastate
02. Interstate
03. Government Vehicle (10,000 lbs. GVWR and over)
04. Not in Commerce (10,001 lbs. GVWR and over)

#### BB. SOURCE OF NAME
01. Log Book
02. Shipping Papers, Truck, Box, or Trip Manifest
03. Driver
04. Side of Vehicle

#### CC. GROSS VEHICLE WEIGHT RATING
01. Under 10,000 Pounds
02. 10,001 to 26,000 Pounds
03. 26,001 Pounds and Over

#### DD. TOTAL NUMBER OF AXLES
Enter the total number of axles including truck and trailer.

#### EE. VEHICLE CONFIGURATION
01. Passenger Car (only if HF in placed)
02. Light Truck (only if HF in placed)
03. Bus/Limousine
04. Single-unit Truck (2 axles)
05. Single-unit Truck (3 or more axles)
06. Truck and Trailer
07. Tractor-Trailer (Semi-Trailer)
08. Bus/Truck Combination
09. Bus/Truck Tractor and Double Trailers
10. Bus/Truck Tractor and Triple Trailers
11. Other (Describe in Narrative)

#### FF. CARGO BODY TYPE
01. Bus/limousine (seats 16 or more occupants including the driver)
02. Bus/limousine (seats 15 or more occupants including the driver)
03. Van/Enclosed Box
04. Cargo Tank
05. Flatbed/Platform
06. Dumper
07. Concrete Mixer
08. Auto Transporter
09. Garbage Hauler
10. Grain, Chips, General
11. Pole
12. Intermodal Container
13. Vehicle Hauling another Vehicle
14. Fire Apparatus
15. Ambulance
16. No Cargo Body
17. Other (Describe in Narrative)

### HH. HAZARDOUS MATERIALS
Did the vehicle have a hazardous material placard?
00. No
01. Yes

### JJ. HAZARDOUS MATERIALS
Was hazardous cargo on the placarded truck released?
00. No
01. Yes

### KK. HAZARDOUS MATERIALS
Enter the four-digit number from the placard. If no number on the placard enter the four-digit identification number from the shipping papers.

#### LL. HAZARDOUS MATERIALS
Enter the one-digit number taken from the bottom of the placard.

### MM. LIQUID HAZARDOUS MATERIALS
Enter the amount of bulk liquid cargo at time of accident.
01. 0 to 1,000 gallons
02. 1,001 to 2,000 gallons
03. 2,001 to 5,000 gallons
04. 5,001 to 10,000 gallons
05. 10,001 to 25,000 gallons
06. 25,001 to 50,000 gallons
07. 50,001 to 100,000 gallons
08. 100,001 to 200,000 gallons
09. 200,001 gallons and over

### GG. Block AA
**Top**

#### NON-COLLISION
01. Ran Off the Road
02. Jackknifed
03. Overturning
04. Drowning in Waterway
05. Cargo Loss or Shift
06. Explosion or Fire
07. Separation of Units
08. Contact the Median/Center Line
09. Equipped Failure (Tire, etc.)
10. Other (Describe in Narrative)

### COLLISION
11. Pedestrian
12. Motor Vehicle in Transport
13. Pedestrian Vehicle
14. Team
15. Pneumatic (Bicycle, Tricycle, etc.)
16. Animal
17. Fixed Object
18. Work Zone Maintenance Equipment
19. Other Moveable Object
20. Other (Describe in Narrative)

### NN. Block AA
**Bottom**